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The Berg Balance Scale: Validation in a Paediatric Population

by

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A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Master of Science

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The undersigned certify that they have read, and recommended to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled *The Berg Balance Scale: Validation in a Paediatric Population* by *Gayatri Kembhavi* in partial fulfillment of the requirements for the degree of *Master of Science.*

DEDICATION

-To my parents, Dilip and Alaka-
for instilling in me a passion for learning, and especially for their loving support at all times

-To my supervisor Johanna Darrah-
for her support and encouragement in this, and in all my endeavours

ABSTRACT

The purpose of the study was to assess the discriminative ability of the BBS compared to the discriminative ability of the Gross Motor Function Measure (GMFM) in a population of ambulatory children with cerebral palsy (CP). The relationship between scores on the BBS and the GMFM was also assessed.

Thirty-six children with CP and 14 typically developing children between the ages of 8 and 12 participated in the study. The children with CP were divided into three diagnostic groups. Each participant was evaluated on the BBS and subscales D and E of the GMFM. A one-way ANOVA was used to analyze significant group differences between BBS and GMFM scores. Correlations between scores on the two measures were determined.

The BBS demonstrated poor discriminatory abilities among the three diagnostic groups of children with CP. The discriminatory abilities improved when the children were reclassified according to gross motor function. The correlation between BBS and GMFM scores was high. The BBS may be an appropriate tool to use with ambulatory children with CP who use ambulatory aids, and who have moderate balance deficits.

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CHAPTER 1

INTRODUCTION

Reliable and valid outcome measures are needed in the field of rehabilitation to establish baseline measures, to demonstrate evidence for the efficacy of treatments, and to provide clients with feedback regarding their strengths and weaknesses. In the rehabilitation of persons with cerebral palsy (CP), this need is especially important. Validated, standardized measures assist therapists in providing parents and caregivers with quantitative information about their child's development, and in identifying problem areas that may not have been apparent through informal observation (Campbell, 1996). Established outcome measures are also important to assess the effectiveness of interventions. According to Campbell (1996), rehabilitation "…would be enhanced by agreement on standard measures for assessing both disability in daily life roles and impairments…" (p. S61). Not only must tools used in rehabilitation be reliable and valid, but also these tools must be appropriate for clinicians. Tools that are prohibitively expensive, time-consuming, or require laboratory testing have little clinical utility.

A careful review of tools currently used with children with CP demonstrated a paucity of clinical tools to measure balance in this population. Balance is one of several systems impaired by the neurological insult causing CP. Although the basic insult is non-progressive, neurological and musculoskeletal impairments can appear to worsen as the child grows and matures and attempts to compensate for abnormalities while moving against gravity (Wilson, 1991). As the musculoskeletal impairments worsen, balance may be

adversely affected. Balance skills are an integral part of gross motor abilities and poor balance causes difficulties with functional tasks involved in activities of daily living. Balance deficits in a functional context become an important issue in rehabilitation, and are often the focus of intervention. Therefore, an outcome measure addressing the construct of functional balance is required. Research on children with cerebral palsy has focused largely on the cause of poor balance in this population, utilizing moving platforms and electromyography. While this research has provided valuable insights into the pathophysiology of balance impairments, these systems are expensive to use and not readily available to clinicians. A reliable, valid and simple tool to measure balance in children with CP would be valuable to clinicians that are involved in the rehabilitation of this population. The purpose of this study was to examine the validity of the use of the Berg Balance Scale (BBS), a functional measure of balance developed for an adult population, with a population of ambulatory children with CP.

Objectives

The primary objective of this study was to evaluate the discriminative abilities of the BBS compared to the discriminatory abilities of the Gross Motor Function Measure (GMFM) (Russell, Rosenbaum, & Gowland, 1993), the gold standard to measure gross motor function in children with CP. Four groups of ambulatory children with differing balance abilities participated in the study: 1) children with typical motor abilities, 2) children with spastic hemiplegia, 3) children with spastic diplegia who ambulate without aids, and 4) children with spastic diplegia who ambulate with aids.

The proposed hierarchy of balance abilities among the groups, from most refined to least refined was:

1. children with typical motor abilities
2. children with spastic hemiplegia
3. children with spastic diplegia who walk without ambulation aids
4. children with spastic diplegia who walk with ambulation aids.

The proposed relationships of the BBS scores among the four groups of children were based on assumptions of each group's balance and motor abilities. Since balance is considered an essential component for ambulation, the average age of independent walking can be used as one indicator of balance and motor abilities. Early independent ambulation typically emerges in children without motor dysfunction by 9 to 17 months of age (Case-Smith & Shortridge, 1996). This group's motor and balance abilities are also assumed to be superior to the other three groups because of their intact neurological systems. The appearance of independent ambulation in children with a diagnosis of spastic hemiplegia can be described as 'late normal', earlier than the majority of children with spastic diplegia (Scrutton & Rosenbaum, 1997). Most studies have found that children with spastic hemiplegia attain independent ambulation between 18 and 27 months of age (Montgomery, 1998). Children with hemiplegia are also thought to have higher-level motor and balance abilities compared to children with spastic diplegia because one arm and leg is normal or minimally involved.

Children with spastic diplegia tend to ambulate at a later age than those with spastic hemiplegia. In one study of children with spastic diplegia, 90% of the children achieved independent ambulation with or without ambulatory aids by 41 months of age (Scrutton & Rosenbaum, 1997). Other studies indicate that the average age of independent ambulation in children with spastic diplegia varies between 36 and 47 months (Montgomery, 1998). Since walking aids are provided to compensate for poor balance, it is reasonable to assume that

children with spastic diplegia who walk without aids possess better balance abilities than those children with spastic diplegia who require ambulation aids.

The secondary objective of this study was to evaluate the relationship between BBS scores and scores on dimensions D (Standing) and E (Walking, Running, and Jumping) of the GMFM, a measure of functional motor abilities.

Hypotheses

To evaluate the primary objective the hypotheses were:

1) Children with typical motor abilities will achieve a higher group mean score on the BBS than children with spastic hemiplegia.

2) Children with spastic hemiplegia will achieve a higher group mean score on the BBS than children with spastic diplegia who are independent ambulators.

3) Children with spastic diplegia who are independent ambulators will achieve a higher group mean score on the BBS than children with spastic diplegia who require aids to ambulate.

A similar hierarchy in GMFM scores was hypothesized.

To evaluate the secondary objective, it was hypothesized that there would be a moderate positive correlation of .40 to .60 between BBS scores and GMFM scores (subscales D and E). This relationship reflected the influence of balance on motor skills assessed in subscales D and E of the GMFM. The correlation was not expected to be extremely high since other parameters such as muscle strength and coordination contribute to the assessed motor skills on the GMFM.

Clinical Relevance

Balance is an important aspect of motor activities, and impairment of balance can cause many functional difficulties. The consequences of balance impairments occur not only in adults, but also in a pediatric population. Children between the ages of 8 and 12 are in the process of learning skills to increase their independence in daily tasks, and any impairment in gross motor skills can impede independence. The treatment of balance impairments makes up a large part of rehabilitation in children with CP. Access to a simple, reliable and valid tool to measure balance would be of great value to therapists working with this population. This research study aimed to evaluate the BBS as such a tool to use with children with spastic hemiplegic or spastic diplegic CP. If the BBS were validated in a population of children with CP, clinicians would be able to identify that a child has a functional balance problem. The nature of the BBS will also allow therapists to pinpoint the area of functional balance in which the child is experiencing problems (i.e., standing with a narrow base, moving within his/her base of support). In addition, therapists will be able to provide families with more specific feedback regarding their child's performance. The BBS does not identify the specific constraints causing the balance impairment. This level of assessment must occur after a functional balance problem has been identified. The BBS has a potential to be an important tool in the evaluation of balance of functional skills in a pediatric population.

CHAPTER 2

LITERATURE REVIEW

Definitions and Terminology

The first challenge facing those who set out to create new tools or to validate existing ones is to reach consensus on the terminology and definitions of the concepts they wish to measure. This challenge is especially apparent in the area of balance. A review of current literature reveals not only lack of agreement on the definition of balance, but also on the terminology used when referring to balance and its constructs. Other terms to describe the concept of balance include "postural control", "postural stability", and "equilibrium". Postural control has been defined as "…the ability to maintain the body's center-of-gravity over the base of support during quiet standing and movement" (Hageman, Leibowitz, & Blanke, 1995, p.961). Other authors have stated that a system is considered stable if it returns to the original or another stable state of posture or motion when perturbed (Patla, Frank, & Winter, 1992). Postural equilibrium is said to be "…the condition in which all the forces acting on the body are balanced such that the center of mass is controlled relative to the base of support, either in a particular position or during movements" (Horak, Henry, & Shumway-Cook, 1997, p.519). Clinically, balance is commonly thought of as being either static or dynamic. Although the term "static balance" implies a lack of movement, there are always subtle postural adjustments made to maintain balance. Dynamic balance implies larger movements, which are either externally or internally driven.

For the purposes of the study, balance will be considered the ability to maintain the center of gravity within the base of support. Balance is used under three distinct circumstances: 1) while maintaining a static position, 2) when stabililizing the body in preparation for voluntary movements, and 3) when reacting to external disturbances (Berg, Maki, Williams, Holliday, & Wood-Dauphinée, 1992a). Stabilization for voluntary movements involves automatic postural adjustments in response to changes in body positions that occur before, during and after a movement (Berg, Wood-Dauphinée, Williams, & Gayton, 1989; Berg et al., 1992a). Reactions to external disturbances generally involve adjustments in response to the displacement, but can be anticipatory. In keeping with this definition, postural control will be considered to be the motor task required to maintain balance (Berg, 1989). The motor task of postural control is either voluntary or involuntary, and is both anticipatory and reactionary. In addition, functional balance will be considered to be those balance abilities required to perform daily movement tasks such as picking up objects from the floor, dressing, or turning back to look at something. On the dimensions of the International Classification of Functioning and Disability from the World Health Organization, functional balance falls into the dimension of activity (World Health Organization, 1999).

Clinical Frameworks of Balance

Clinical frameworks of balance and postural control have evolved over the years, and have influenced the assessment and treatment of balance disorders. Early work by Sherrington (1947) provided the basis for the classical reflex model of motor control. Sherrington (1947) described the simple reflex as an end-effect produced by a conductor that was stimulated by an input to the nervous system. The coordination or compounding of

reflexes resulted in movement (Barnes, Crutchfield, & Heriza, 1984). Sherrington (1947) stressed that every reflex must be purposive, although they did not have a connection to 'psychical' events. In other words, conscious thought did not have to play a part in reflexes, and therefore movement. Sherrington (1947) did state, however, that reflex arcs were controllable by higher centres, which were driven by conscious thought. The cerebral cortex was described as the "organ of, and for, the adaptation of nervous reactions" (Sherrington, 1947, p. 390). Later work by engineers on closed-loop feedback systems introduced the concept of a feedback mechanism to the reflex model of motor control (Horak, 1991). The three major assumptions of the reflex model are: 1) sensory inputs control motor output; 2) sensation is required for action to occur; and 3) movement is a result of the compounding of reflexes (Sherrington, 1947). Assessment of clients with balance disorders based on the reflex model entailed identifying all the reflexes influencing their movement. Treatment of balance disorders emphasized that therapists should stimulate reflexes that produced "normal" movements, and inhibit those reflexes that produced "abnormal" movements. The reflex model does not provide adequate explanation for centrally driven movements initiated without sensory input, or for anticipatory movement control.

The hierarchical model incorporates some principles found in the reflex model, but states that movement is organized hierarchically in the nervous system. The higher centres of control (the cortex and midbrain) receive input. These higher centres then select the appropriate motor program, and 'instruct' the lower level spinal cord to initiate an output. The musculoskeletal system is the lowest in the hierarchy, and produces the observable movement (Mathiowetz & Haugen, 1994). While reflexes are still driven by sensory stimuli, the hierarchical model allows for volitional movement that is initiated by the person's will and desire to move. It is believed that the higher centers of control exert an influence over the

lower centres, inhibiting primitive reflexes and allowing for refined movement to occur. The development of postural control involves the inhibition or integration of the reflexes by higher centres of control (Woollacott, Shumway-Cook, & Williams, 1989). Initially, primitive reflexes that are controlled by the spinal cord, pons, and medulla of the midbrain dominate movement. As the infant matures, the midbrain and thalamus exert increased influence over lower centres allowing for the emergence of righting reactions. In this step-wise manner, the cerebral cortex begins to control the lower centres, allowing for the appearance of equilibrium reactions, which define mature balance. Maturation of the nervous system in this way causes modification of reflexes by supraspinal or cortical centres through excitation or inhibition (Barnes et al., 1984).

Lesions of the nervous system are said to disrupt the influence of higher centres of control on the lower centres. As a result, lower level reflexes dominate movement. Using this theoretical framework, balance assessment concentrates on evaluating the presence or absence of primitive reflexes, righting reactions and equilibrium reactions. Poor postural control and balance impairments are said to be a result of an incomplete or an absence of integration of primitive reflexes. Dominance of lower centres of control over movement cause a delay in the development of mature postural responses and balance control. Treatment approaches to balance impairments focus on inhibiting primitive reflexes to promote mature postural control responses (Shumway-Cook & Woollacott, 1995), and facilitating higher-level righting and equilibrium reactions. Recovery of the nervous system from an insult is said to be step-wise, as is the control of movement. Consequently, treatment is often designed to progress from eliciting the most automatic movement skills to the least automatic. For example, righting reactions are elicited before equilibrium reactions.

Modifications to the hierarchical theory allow for horizontal and vertical control of movement, as opposed to strictly vertical control. According to Barnes et al. (1984), horizontal control is a result of the broadening of the maturing neural network, thus allowing for a greater variation of movement and a larger range of possible responses to stimuli. The modified theory also allows for control of lower centres over higher centers depending on the task to be completed. In addition, reflexes are no longer thought of as the sole determinant of postural control (Shumway-Cook & Woollacott, 1995). The most important change to both the reflex and hierarchical theories in terms of balance is that postural control is viewed as the result of complex interactions among several neural systems (Horak & Macpherson, 1996). These neural systems further interact with biomechanical constraints of the body to achieve postural stability. These neural behaviors are automatic and task-specific (Horak & Macpherson, 1996).

Nashner (1979) has conducted extensive research into mechanisms of postural control, and motor control exhibited during postural control activities. While much of his work is based on the hierarchical model of motor control, he acknowledges the influence of the external environment on motor activities. He states that, "the sensorimotor system expresses purposeful movements, adapts these movements to the external conditions and loads, and maintains the posture and balance of the body utilizing a hierarchy of specialized subsystems" (Nashner, 1979). Much of Nashner's research involves having subjects stand on a moving platform while electromyographic readings are taken of lower extremity muscle activity (e.g., Nashner, 1979; 1983). Results of this research suggest that the body activates muscles in groups called synergies to adjust to changes in sensory inputs and perturbations from the external environment. Nashner suggests that while a hierarchical system of motor activation for postural control exists, the motor system must delegate the control functions

among the different levels of the system (Nashner, 1979). While the local systems are important in generating and coordinating simple movements, the higher central systems are involved in adaptive and balance tasks. Recent work by neuroscientists indicates that the control of balance is both hierarchical, and heterarchical (Forssberg & Nashner, 1982). Ongoing work in the area of neuroscience acknowledges the influence of external factors on the control of balance, while still maintaining the hierarchical/heterarchical control of balance by the nervous system. Postural control is constrained not only by the nervous system, but also by the muscular and skeletal systems, as well as the environment in which movement must occur (Sveistrup & Woollacott, 1993).

While the hierarchical model is widely accepted among therapists, it does have several limitations. First, some complex movements such as walking have been shown to occur in the absence of influences from higher centres of control, indicating control of strictly lower centres. Second, the hierarchical model assumes that development of motor and postural control is stepwise, moving from reflexively driven to internally initiated movements (Horak, 1991). Third, although the role of the environment has been acknowledged in recent work examining the hierarchical theory, it may play a larger role in balance control than the theory suggests. Last, an unlimited number of central programs would be necessary to carry out movement in varied contexts (Mathiowetz & Haugen, 1994).

Concurrent to the development of the hierarchical model of motor control was the emergence of the dynamic systems theory of motor control. The dynamic systems model suggests that there are multiple biomechanical, neurological, and environmental systems that interact to achieve the goal of maintaining balance, or postural control (Woollacott & Shumway-Cook, 1990). Rather than viewing balance control as a reactive response to stimuli, the systems theory advocates a goal-directed organization that is proactive, adaptive and

based on previous experiences and intentions (Horak et al., 1997). The interaction among systems is determined by task goals, and as such, there may be multiple solutions to accomplishing a movement goal (Bradley, 1994). The interacting systems include internal factors such as muscle tone, strength, and joint range of motion, as well as the environment and its constraints. The nervous system in the dynamic systems model is thought to be heterarchically organized such that the higher centres do not control the lower centres; rather they work in conjunction with them (Mathiowetz & Haugen, 1994). All systems contribute to control on the same level. The nervous system continually adapts to and predicts constraints placed on movement by both internal and external factors. Motor behavior is impacted by all the subsystems and further influenced by the task (Piper & Darrah, 1994). Given that there are many systems which all contribute to postural control strategies, maturation of several components of the system is necessary before higher-level balance strategies can emerge (Shumway-Cook, 1989).

In this model, assessment of functional balance involves the identification of all the possible constraints in the system that may be contributing factors to balance deficits in a functional context. Therapists must carefully assess each factor in order to identify accurately the system or systems that may be causing the limitations. After a balance deficit is determined, possible constraints in the child, environment or task contributing to the balance difficulty are identified. These constraints may be different for each child. This model suggests that if the constraint(s) is/are removed or modified then the child will be able to perform the desired task. The systems model of balance control was the first to advocate the assessment of balance in a functional context. It is critical to work on identifiable, functional tasks, as the assumption is that movements are organized around behavioral goals. A distinct advantage of the systems model over both the reflex and the hierarchical models is that it can

account for the flexibility of motor tasks in various external conditions. One limitation of this model is that abnormalities in one system may cause deficits in another (Shumway-Cook, 1989). As a result, the true cause for a balance deficit, for example, may be masked by the secondary deficits. Therapists must ensure that they identify all areas of limitations, and address all systems that may be constraints to movement.

Maturation of Balance

Sensory Systems

Three sensory systems interact in order to maintain balance: the visual, the somatosensory and the vestibular (Berg, 1989; Cohen, Blatchly, & Gombash, 1993; Foudriat, Fabio, & Anderson, 1993; Frank & Earl, 1990; Richardson, Atwater, Crowe, & Deitz, 1992; Shumway-Cook & Horak, 1986; Westcott, Lowes, & Richardson, 1997). Sensory information from the visual, somatosensory and vestibular systems interacts to produce the postural adjustments required to maintain balance. Much research has been conducted on these three systems, and the roles they play in balance throughout development and aging. Healthy adults appear to rely primarily on feedback from the somatosensory system to maintain balance under normal sensory conditions (Woollacott & Shumway-Cook, 1990). The visual system is essential in stabilizing postural control (Hageman et al., 1995). In adults, the vestibular system appears to play a role in resolving conflicts between the somatosensory and visual systems (Berg, 1989; Foudriat et al., 1993; Westcott et al., 1997). Losses in visual acuity, decreased vibration and pressure sense and changes to the vestibular system all adversely affect balance (Berg, 1989). Reaction times are generally slowed. As speed and

accuracy of responses are required for adequate postural responses, this causes difficulties in maintaining balance (Hageman et al., 1995).

Children exhibit different methods of maintaining balance. The visual system is of primary importance in the maintenance of balance in young children under the age of three (Foudriat et al., 1993; Hayes & Riach, 1989; Westcott et al., 1997; Woollacott & Shumway-Cook, 1990). Before the age of seven, children are unable to rely solely on their vestibular system to balance (Woollacott & Shumway-Cook, 1990). Between the ages of four and six, the somatosensory system plays a larger role in balance strategies (Westcott et al., 1997). Forssberg and Nashner (1982) found that children's balance performance was not compromised greatly without visual information or conflicting vestibular information as long as the support surface provided useful and accurate information. By the age of seven, children exhibit adult-like balance control, and are able to use all three systems efficiently. When compared to adults, children were found to have greater variability in their postural control, especially those under the age of seven. This is thought to be due to children randomly changing the weighting of visual, vestibular and somatosensory input in achieving balance control (Forssberg & Nashner, 1982). After seven years of age, children appropriately resolve conflicting information from the visual and somatosensory systems by using their vestibular system (Westcott et al., 1997). It is also after the age of seven that gait matures and exhibits adult-like qualities.

Balance Synergies and Strategies

The central nervous system organizes muscles into groups that act together to maintain balance, known as muscle synergies (Nashner, 1979). These synergies are defined as "the functional coupling of groups of muscles such that they are constrained to act together

as a unit" (Shumway-Cook & Woollacott, 1995, p.127). Muscle synergies were thought to be "hardwired" and inflexible. Recent research has demonstrated that these synergies are flexible, and although still thought to be centrally organized, are responsive to the initial stimulus, characteristics of the perturbation, and learning (Horak et al., 1997). These synergies can occur in preparation for an activity, can accompany a movement to minimize the postural disturbance, or can occur in reaction to a disturbance (Frank & Earl, 1990). Those couplings that are more distal tend to be activated before the more proximal synergies. In general, postural control strategies and muscle synergies are thought to occur as either a feedforward mechanism, or a feedback mechanism (Haas, Diener, Rapp, & Dichgans, 1989). If the synergy is activated in response to a movement disturbance, it is considered a feedback mechanism to maintain upright balance. If the synergy is activated in preparation for a movement or disturbance, it is considered to be a feedforward mechanism. According to Haas et al. (1989), feedback control develops before feedforward control in children. Feedback control is not fully mature, however, when feedforward control emerges, and both continue to develop throughout childhood. This continuing development is reflected in increasing motor skills and improved adaptations to biomechanical demands. As children become older, postural feedforward adjustments become more refined and specific to the task being performed (Hayes & Riach, 1989).

Postural control strategies incorporate not only muscle synergies, but also joint torque and kinematics. The overall goal of the postural control strategies is to maintain external stability of the body (Patla et al., 1992), but the specific strategies used are highly task-specific. There are three distinct strategies used to maintain balance: the ankle strategy, the hip strategy, and the stepping strategy. The strategy used in a particular situation depends on the biomechanical, neurological and environmental constraints imposed on the person (Horak

et al., 1997). Further, these strategies are limited by the sensory information provided by the environment (Horak et al., 1997). The ankle strategy involves distal- to- proximal muscle activation to maintain the body's center of gravity with the base of support through movement centered around the ankle (Horak et al., 1997; Shumway-Cook & Woollacott, 1995). Nashner et al. (1989) showed that the ankle strategy was effective for low frequency movement of the centre of gravity as the moment of body inertia about the ankles is large. The ankle strategy is effective for backward and forward leaning positions. The hip strategy involves activation of proximal hip and trunk muscles to move the centre of gravity more rapidly than the ankle strategy (Nashner, Shupert, Horak, & Black, 1989). According to Nashner et al. (1989), hip strategies are effective when standing on small support surface areas. The stepping strategy uses activation of both proximal hip muscles and co-activation of ankle agonist and antagonist muscles (Horak et al., 1997). Neurologically intact adults and older children can use a mixture of these three strategies and can shift quickly from one strategy to another to maintain balance (Shumway-Cook & Woollacott, 1995, p.130).

Research with typically developing children has offered insights into the development of postural control strategies in children. Until children are able to stand and walk independently, organized leg muscle activation is not seen (Woollacott & Burtner, 1996; Woollacott et al., 1989). Fifteen month to three year old children demonstrate a consistent distal-to-proximal response pattern in reaction to external disturbances. Although the distal-to-proximal pattern exists in young children, there appears to be increased co-activation of the four postural muscles in the legs (gastrocnemius, tibialis anterior, hamstrings and quadriceps) (Forssberg & Nashner, 1982). Between the ages of four and six, there appears to be a regression in the child's ability to organize postural control responses (Woollacott & Shumway-Cook, 1990; Woollacott et al., 1989). Latencies of responses are longer in this age

group than in those found in children between the ages of fifteen months and three years and in children seven years of age and older. Children below the age of seven show slower responses than older children and adults to postural perturbations (Forssberg & Nashner, 1982). By the age of seven, the variability of responses is reduced significantly, and the postural control responses are essentially adult-like (Woollacott & Shumway-Cook, 1990). Generally, in children with typical motor development, maturation of balance emerges as the duration of postural responses is reduced and there is less activation of antagonistic muscles (Woollacott & Burtner, 1996). Forssberg and Nashner (1982) state that although the components of postural activity are developed in young children, the processes to modify these components to suit environmental or task demands are not, thus lending support to the hierarchical framework of balance control.

Summary Statement

Theoretical frameworks of balance have moved from a strictly reflexive viewpoint to one that incorporates factors inherent to the person and the environment. Neuroscience research has revealed that balance in typically developing children is not mature until the age of seven or eight. Up to this age, children exhibit similar patterns of muscle activation as adults, but not in an organized fashion. Children also rely more heavily on their visual system than their somatosensory or vestibular systems to maintain their balance. Research findings and the evolution of theoretical constructs have shaped clinicians' approaches to the assessment and treatment of balance disorders in children.

Cerebral Palsy

Pathophysiology

Cerebral palsy (CP) is a term used to describe a non-progressive neurological defect or insult to the immature brain in single or multiple locations before, during, or shortly after birth (Olney & Wright, 1994; Shepherd, 1995). CP is characterized by impaired voluntary motor control and coordination, and can be accompanied by sensory deficits, mental impairments, and seizure disorders. Several risk factors have been identified as being associated with CP (Davis, 1997). Intracranial hemorrhage in infants, especially pre-term infants is an established cause of CP (Olney & Wright, 1994). Although not causative, there are several factors that are associated with a large number of cases, including pre-term birth (Olney & Wright, 1994), and both prenatal and perinatal factors (Davis, 1997). Clinically, CP is classified according to the distribution of the impairment on the area of the body, for example, monoplegia, hemiplegia or diplegia. It is also described in terms of the perception of tone and involuntary movements, for example, spastic (hypertonic), ataxic or athetoid (Shepherd, 1995). Although the initial insult is non-progressive, the musculoskeletal manifestations of the condition can progress. This is especially so with adaptive changes in muscle length which in some cases lead to skeletal deformities. The impaired voluntary motor control in children with CP also manifests itself in disorders of balance control.

Balance Control

Children with CP experience muscle incoordination problems, difficulties with the organization of sensory information, and are influenced by increased tone in their upper and

lower extremities. These factors increase the difficulty of postural control (Liao, Jeng, Lai, Cheng, & Hu, 1997). Balance strategies of children with CP appear different than the strategies of neurologically intact children. They demonstrate increased co-contractions of distal and proximal muscles, and do not have a smooth distal-to-proximal pattern of muscle activation (Woollacott & Burtner, 1996). Nashner et al. (1983) found that unlike typically developing subjects, children with CP demonstrated a reversed order of activation of distal and proximal muscle synergies in response to a moving platform. In research with children with spastic hemiplegia, Nashner also found coordination problems in the non-involved leg during platform perturbations that involved both legs (Nashner, Shumway-Cook, & Marin, 1983). Not only was there a reversal of synergy activation in the involved leg, but also in the involved arm. Children with a diagnosis of CP also show increased antagonistic muscle co-activation as compared to children with typical motor development (Nashner et al., 1983; Woollacott & Burtner, 1996). Results of the study by Woollacott et al. (1996) suggest that biomechanical factors and impairments of musculoskeletal alignment are important factors in muscle activation in response to postural perturbations in children with CP. These findings also support the contention that postural control functions are executed by specialized subsystems of the nervous system (Nashner et al., 1983).

Outcome Measures for Balance Assessment in Children

While several tools are used to measure balance in children, they are limited in their use to assess functional balance with children with CP. First, many motor developmental scales are used to assess balance abilities. The items on these scales represent typical motor development. As a result, children with motor disabilities can do very few of the items and the tests are unresponsive to small changes. Also, these tools have not been validated to

measure balance, but rather motor skills. Two of these tools are the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP) (Bruininks, 1978), and the Peabody Developmental Motor Scales (PDMS) (Folio & Fewell, 1983). The BOTMP is a norm-referenced test designed for use with children with mild motor impairments and developmentally handicapped children between the ages of 4 ½ and 14 ½ (Brenneman, 1994; Westcott et al., 1997). It is difficult for children with more severe motor impairments to complete (Westcott et al., 1997), thus of little clinical utility with a population of children with CP. The PDMS is a norm-referenced, and criterion-referenced tool. It was developed in response to the need for educational programming for children with disabilities, specifically physical education programming. The PDMS measures gross and fine motor development of children between birth and 83 months. The items of the PDMS are based on the typical sequence of motor development. The gross motor scale does include a balance subscale (Folio & Fewell, 1983), but again, children with severe motor disabilities, such as CP, can do few of these items.

Second, some balance tools measure the balance deficit at the level of the impairment, rather than function, and assess impairments such as those found in the vestibular and somatosensory systems. Two such tools are the Functional Reach Test (Niznik, Turner, & Worrell, 1995) and the Pediatric Clinical Test of Sensory Integration for Balance (Crowe, Deitz, Richardson, & Atwater, 1990). Duncan et al. (1990) developed the Functional Reach Test (FRT) to assess balance in the elderly. In contrast to many of the available laboratory tools, the FRT is used to assess balance during internally driven perturbations. Duncan et al. (1990) define functional reach as "the maximal distance one can reach forward beyond arm's length, while maintaining a fixed base of support in the standing position" (Duncan, Weiner, Chandler, & Studenski, 1990, p. M192). The FRT was also studied for use in a population of children with lower extremity spasticity, including children with cerebral palsy, between the

ages of five and fifteen (Niznik et al., 1995). The results of this study suggested that the FRT had strong intra-rater reliability (r = .94 and .87). Further research, however, concluded that it had weak test-retest reliability (r = -.31 - .34) with children with developmental delay, thus was not recommended for use with children with disabilities without further testing (Westcott et al., 1997). The P-CTSIB was adapted from the Clinical Test of Sensory Interaction for Balance developed by Shumway-Cook and Horak (1986) to assess the contributions of sensory information to the standing balance in children (Crowe et al., 1990). It uses six sensory conditions and assesses postural sway in these six conditions (Richardson et al., 1992). The six conditions are: 1) eyes open, standing on a hard, flat surface; 2) eyes closed, standing on a hard, flat surface; 3) eyes open, standing on medium density foam; 4) eyes closed, standing on medium density foam; 5) eyes open, standing on a hard, flat surface with a visual conflict dome over the head; and 6) eyes open, standing on medium density foam, with a visual conflict dome. Initial studies have demonstrated moderate to strong inter-rater reliability (.69 - .92) (Crowe et al., 1990), and slightly lower test-retest reliability (.45 - .78) (Westcott, Crowe, Deitz, & Richardson, 1994). All published studies to date have been performed on typically developing children between the ages of four and nine (Crowe et al., 1990; Richardson et al., 1992; Westcott et al., 1994).

The third type of balance test has to be administered in a laboratory setting, and involves using a moving platform and varying visual conditions (Berg, 1989; Berg et al., 1992a; Westcott et al., 1997). These laboratory conditions are difficult to transfer to a clinical setting. Several researchers have assessed tilt-board tests as measures of balance in children (Atwater, Crowe, Deitz, & Richardson, 1990; Broadstone, Westcott, & Deitz, 1993). Both studies used children between the ages of four and nine. One study examined balance in both typically developing and developmentally delayed children (Broadstone et al., 1993),

while the other assessed only typically developing children (Atwater et al., 1990). In both cases, test-retest reliability was poor (r = .45 and ICC = .49 - .54), and researchers suggested further study before tilt-boards were implemented in the assessment of balance in children (Atwater et al., 1990; Broadstone et al., 1993). Atwater et al. (1990) did find, however, that the inter-rater reliability of the tilt-board tests was high (r = .98). There has been no published research to date using the tilt-board tests with children with CP.

The Berg Balance Scale

The Berg Balance Scale (BBS) (Appendix A) was developed to measure balance in the elderly and the neurologically impaired individual in a clinical setting. The focus of the BBS is performance, rather than the underlying impairment of poor balance (Berg et al., 1989). It is a simple tool, which requires little training, minimal equipment and only 15 to 20 minutes to administer (Berg et al., 1989; Cole, Finch, Gowland, & Mayo, 1994). The BBS is considered a gold standard of the evaluation of balance performance with the elderly (Liston & Brouwer, 1996). Inter-rater reliability of the BBS is extremely high, with an intra-class correlation coefficient of .98 (Berg et al., 1989; Liston & Brouwer, 1996). Similarly, intra-rater reliability is high with a reported correlation coefficient of .99 (Berg et al., 1989). A further validation study by Berg et al. (1992) illustrated that scores on the BBS showed correlations of .91 with the Tinetti Balance Subscale (Tinetti, 1986) and -.76 with the Timed "Up and Go" Test (Podsiadlo & Richardson, 1991), two functional measures. The same study ascertained that the BBS is able to predict falls in the elderly, and demonstrated good discriminative ability between groups of subjects with differing levels of balance control, in particular, those subjects who required aids to ambulate, and those who did not (Berg, Wood-Dauphinée, Williams, & Maki, 1992b). The correlation between the BBS and balance

parameters measured on laboratory equipment was poor to moderate, ranging from .20 to -.67 (Berg et al., 1992a).

The BBS has potential to be used with a pediatric population. Berg (1989) states that "... the scale may well apply to any population with balance impairment, regardless of age". By the age of eight, children's balance skills have achieved adult-qualities. Unlike other balance measures for children, the BBS emphasizes function, and captures a wide range of abilities. It is also quick and simple to administer. These features of the BBS make it an appropriate measure to consider for use with a pediatric population.

Summary

The construct of balance is one that has long been of interest in rehabilitation. Balance is a necessary requirement to perform daily tasks. Over the past half-century, the theoretical frameworks dealing with balance and motor control have moved from a reflex/hierarchical perspective to a dynamic systems model. The emphasis of the systems model is function, as opposed to the underlying balance impairment. Much of the emphasis in paediatric rehabilitation is placed on improving balance as it plays an important role in a child's ability to perform basic gross motor tasks (Westcott et al., 1997). A review of recent literature has revealed a paucity of outcome measures available to measure functional balance in children with a diagnosis of CP. Current measures of balance in paediatrics lack functional context and clinical utility. The Berg Balance Scale appears to merit consideration for use in a paediatric population, given its simple format based on functional balance skills required for activities of daily living.

CHAPTER 3

METHODOLOGY

Design

An observational, cross-sectional design was used for this study. Ethical approval for the study was received from the Capital Health Authority Health Research Ethics Board prior to commencement of the study.

Study Participants

Ambulatory children with CP in the three diagnostic groups were identified from clients currently registered in either the Physical Medicine Clinic or the Orthopaedic Treatment Clinic at the Glenrose Rehabilitation Hospital. The sample was drawn using a non-random quota sampling technique. Clinic lists were reviewed by the primary investigator to identify those children between the ages of eight and twelve with diagnoses of either spastic hemiplegic or spastic diplegic CP. Children with severe behavioral problems, as identified by the clinic coordinator or treating therapist, were excluded from the study, as both the BBS and the GMFM require a child to focus on a task for approximately 20 minutes. A diagnosis of attention deficit-hyperactivity disorder was not sufficient cause for exclusion as this disorder may have been controlled adequately by medication. Subjects who had undergone orthopaedic surgery within six months of testing were excluded, as their functional status may still have been compromised from the surgery, and may not have been representative of the usual performance of children in their diagnostic category.

The diagnoses of spastic hemiplegia and spastic diplegia were chosen because children with these diagnoses constitute approximately 78% of all children with CP (Olney & Wright, 1994), and they are appropriate for testing with the items on the BBS. The age range of eight to twelve years was based on studies which have shown that mature postural responses are not attained until after the age of seven in typically developing children (Westcott et al., 1997). Children in this age group are also often treated intensively by physical therapists in order to attain maximal functional abilities. Based on sample size calculations (Appendix B), approximately 13 subjects per group were required to satisfy the first objective. Sample size calculations for the second objective (Appendix B) indicated that a total of 41 subjects were required for the study. A sample size of 15 subjects per diagnostic category was targeted. A letter of invitation and pamphlet explaining the study was mailed to appropriate families (Appendix C). Children were recruited into the study once their parents responded to the letter of invitation by agreeing to allow their child to participate. Children without a diagnosis of CP were initially recruited by asking the children with CP to identify friends or classmates. This method of recruitment was not successful, so typically developing children were recruited from acquaintances of the principal investigator.

The gender of subjects was not considered a confounding factor, as research into the balance of normally developing children has not shown any significant difference between males and females (Richardson et al., 1992). Extremely high-functioning children with CP were naturally excluded from the study since they are not followed at either the Physical Medicine Clinic or the Orthopaedic Treatment Clinic. Tonus and distribution are commonly used to classify children with CP, and thus were used in this study to allocate children into the three experimental groups.

Measures

In the area of balance assessment in children with CP, there are no tools currently available that are considered gold standards of balance assessment. It is generally accepted that a gold standard is required when establishing the concurrent validity of a new tool introduced for that population. The GMFM is now considered a gold standard in the assessment of motor function in children with CP, but not specifically in the evaluation of balance. Boyce et al. (1992) faced a comparable challenge when developing the Gross Motor Performance Measure. As was done by Boyce et al. (1992), an a priori hypothesis was formulated about how scores on the BBS would relate to scores on dimensions D (Standing) and E (Walking, Running and Jumping) of the GMFM. It was felt that these two dimensions of the GMFM assessed the construct of balance as a component of overall gross motor function and thus the GMFM was considered the best measure to use for concurrent validity with the BBS.

The Berg Balance Scale

The BBS (Appendix A) is made up of 14 items of increasing difficulty. These items test functional skills relevant to everyday tasks, such as moving from sitting to standing, and reaching beyond one's base of support. Items test a client's ability to maintain a position within a decreasing base of support and to change positions. The items are to be performed within a set time frame, or the positions are to be held for a set amount of time. The items are scored on a five-point ordinal scale from 0 to 4, allowing for a maximum score of 56 points (Cole et al., 1994). A higher score indicates better balance abilities. The total time to administer the BBS is from 20 to 30 minutes. No formal training is required to administer the BBS.

The Gross Motor Function Measure

The GMFM (Russell et al., 1993) (Appendix F) is an evaluative and discriminative tool (Westcott et al., 1997) that has been developed specifically for use with children with CP to assess gross motor skills. Items on the GMFM include those that challenge balance and require transitions between postures by altering weight distributions (Campbell, 1996). The five dimensions of the GMFM are: lying and rolling; crawling and kneeling; sitting; standing; and walking, running, and jumping (Cole et al., 1994; Russell et al., 1993). The GMFM is scored on a four-point ordinal scale from 0 to 3. As not all of the five dimensions have the same number of items, a percent score is calculated for each dimension. Calculating the mean percent score for all five dimensions provides the total percent score (Russell et al., 1993). Studies by Russell et al. (1993) indicate that the test has excellent inter-rater ($r = .99$) and intra-rater reliability ($r = .99$). A study from Sweden found an inter-rater reliability of .88 and intra-rater reliability of .68 (Nordmark, Hägglund, & Jarnlo, 1997). The authors of the GMFM have stated that the reliability and validity of the GMFM will not be altered if the dimensions are used separately from the tool as a whole (Russell et al., 1993). A higher score indicates superior gross motor function. For the purposes of this study, raw scores of dimensions D and E were used, rather than percent scores. The GMFM has a formal training process consisting of training workshops and the use of criterion videotapes. The authors recommend that users test at least two children as a practice exercise prior to the use of the GMFM in clinical practice (Russell et al., 1993). Only three items are identical between the 37 items of dimensions D and E of the GMFM, and the 14 items of the BBS.

Data Collection

Independent raters who were unaware of the hypotheses of the study administered each scale. The raters were physical therapists employed at the Glenrose Rehabilitation Hospital. In order to eliminate rater bias across the two tests, one rater administered the BBS, the other the GMFM. The BBS rater underwent training to achieve 80% or greater agreement with gold-standard training videotapes. The GMFM rater was formally trained in the administration of the GMFM. Written consent was obtained from both the children and their parent(s) prior to the commencement of testing. Administration of both tests took between 30 and 45 minutes in total. Testing on the BBS took approximately 10 to 15 minutes. The children were offered a rest break of up to 15 minutes between tests. The majority declined this rest and did both tests without a break. Administration of the GMFM took 15 to 20 minutes per child. The order of testing was randomized by having the children choose a number from a hat to determine which test they performed first. Most parents or guardians observed testing from a distance in the same room. Testing was conducted at a time that was convenient for the family at the Glenrose Hospital. The principal investigator observed most assessments. The children were permitted to wear their orthoses (if any), and shoes, but not permitted to use ambulatory aids for either test.

Statistical Analyses

Both the BBS and the GMFM are scored on an ordinal level. Previous research on both the BBS and the GMFM has analyzed the results on an interval level using parametric statistics. In order to allow for ease of comparison with current research, the data collected in this study was analyzed on an interval level. Scores attained on both BBS and the GMFM

were described using means and standard deviations. Inferential statistics to assess the discriminant validity of the BBS scores were performed using a one-way analysis of variance (ANOVA) to determine if a significant mean difference was present among the four groups. Post-hoc analyses using a Tukey HSD test were conducted to determine the location of the pair-wise differences if the ANOVA result was significant. In addition, the means and standard deviations of BBS scores obtained by the groups were examined for overlap using box and whisker plots. Similar analyses were performed on GMFM scores. An ANOVA was also performed on the mean ages of the children in the four groups to determine that there were no significant age differences among the four groups.

To assess the relationship between scores attained on the BBS and the GMFM, a Pearson product moment correlation coefficient was calculated. Data from all four groups was analyzed together to determine the overall relationship between the BBS and the GMFM. In addition, data from the groups was analyzed separately to determine which group demonstrated the highest level of correlation. For all statistical analyses, an alpha level of .05 was used.

CHAPTER 4

RESULTS

Descriptive Statistics

A total of 50 children participated in the study. There were 32 boys and 28 girls. The mean age of the total group was 10.46 years (SD = 1.38 years) and a range of ages from 8.07 to 12.99 years. The children were divided into diagnostic groups. Descriptive information for each diagnostic subgroup is provided in Table 4.1. The ambulatory aids used by the participants in group three ranged from one Lofstrand crutch (1 subject), to a pair of Lofstrand crutches (2 subjects), to rollator or Kaye walkers (3 subjects). The remaining four subjects used both crutches and walkers depending on the distance they had to ambulate.

Table 4.1 Average age of subjects by diagnostic group

Diagnosis (Group)	N	Gender	Mean Age (years)	Standard Deviation (years)	Range (years)
Spastic Hemiplegia (1)	14	M= 6 F=8	10.35	1.50	8.17-12.99
Spastic Diplegia (no aids) (2)	12	M=9 F=3	10.68	1.17	8.15-11.92
Spastic Diplegia (aids) (3)	10	M=6 F=4	10.18	1.54	8.07-12.32
Typically Developing (4)	14	M=11 F=3	10.57	1.40	8.10-12.90

An ANOVA was performed on the mean ages of the children in the four groups. No significant differences were found among the four groups ($F = 0.28$, $df_{3,46}$, $p \leq .84$).

Analyses of Discriminative Abilities

Analyses using four diagnostic groups

The mean scores and standard deviations (SD) achieved on the BBS and the GMFM by the diagnostic groups are reported in Table 4.2. All GMFM values are reported as raw scores.

Table 4.2 Mean raw scores on the BBS and the GMFM

	BBS score (max. = 56)		GMFM raw score (max. = 111)	
Diagnosis	Mean	SD	Mean	SD
Spastic Hemiplegia (n=14)	53.21	6.49	100.29	14.97
Spastic Diplegia (no aids) (n=12)	49.75	6.73	88.42	18.85
Spastic Diplegia (aids) (n=10)	25.10	12.37	37.60	16.18
Typically Developing (n=14)	55.86	0.36	110.93	0.27
Total Group (n=50)	47.50	13.51	87.88	29.98

The results of the ANOVA analyses for the BBS and GMFM scores are reported in Tables 4.3 and 4.4 respectively. Both ANOVAs were significant. Post-hoc analysis for the

BBS revealed significant pair-wise differences among the group of children with spastic diplegia who used aids and all other groups (Table 4.5). Post-hoc analysis performed for the GMFM also revealed significant pair-wise differences between children with spastic diplegia who use aids and all other groups and between children with spastic diplegia who did not use aids and typically developing children (Table 4.6). Similar ANOVA analyses were performed using the GMFM subscales D and E. The findings of these analyses were the same as the results for the GMFM combined scores. The analyses were repeated using percent scores in place of raw scores. The results were identical. Box and whisker plots found in Figures 4.1 and 4.2 illustrate the BBS and GMFM findings.

Table 4.3 ANOVA results for BBS scores

	Sum of Squares	df	Mean Square	F	Significance
Between Groups	6513.28	3	2171.09	41.18	$p < .01$
Within Groups	2425.22	46	52.72		
Total	8938.50	49			

Table 4.4 ANOVA results for GMFM scores

	Sum of Squares	df	Mean Square	F	Significance
Between Groups	34876.18	3	11625.39	58.53	$p < .01$
Within Groups	9179.10	46	199.55		
Total	44055.28	49			

Table 4.5 Post-hoc Tukey HSD for BBS scores

Mean Difference				
	Typically Developing	Spastic Hemiplegic	Spastic Diplegic (no aids)	Spastic Diplegic (aids)
Typically Developing	-	-2.64 p = .77	6.11 p = .16	30.76 $p \leq .001$
Spastic Hemiplegic		-	3.46 p = .622	28.11 $p \leq .001$
Spastic Diplegic (no aids)			-	24.65 $p \leq .001$
Spastic Diplegic (aids)				-

Table 4.6 Post-hoc Tukey HSD for GMFM scores

Mean Difference				
	Typically Developing	Spastic Hemiplegic	Spastic Diplegic (no aids)	Spastic Diplegic (aids)
Typically Developing	-	10.64 p = .21	22.51 p = .001	73.33 $p \leq .001$
Spastic Hemiplegic		-	11.87 p = .16	62.69 $p \leq .001$
Spastic Diplegic (no aids)			-	50.82 $p \leq .001$
Spastic Diplegic (aids)				-

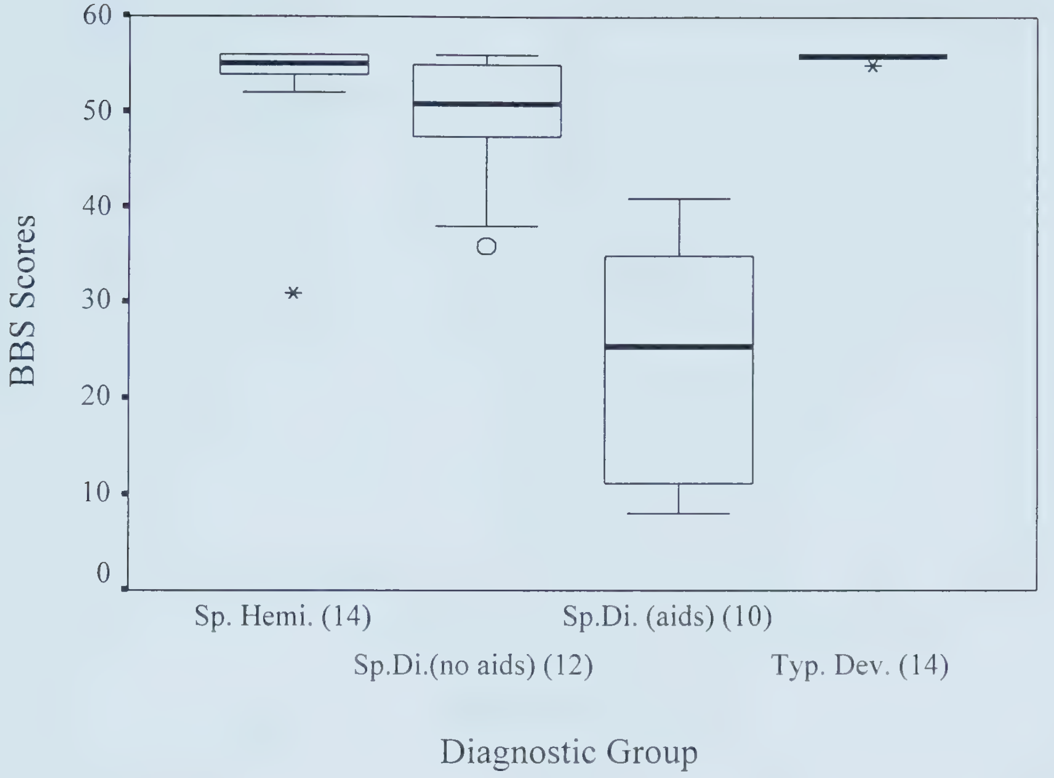
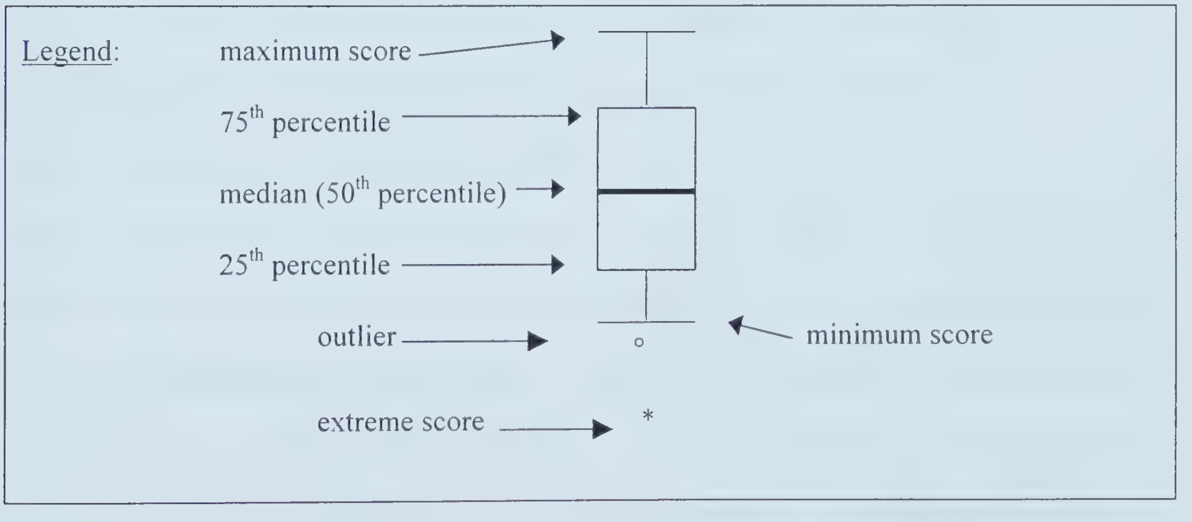


Figure 4.1 Box and whisker plots of BBS scores of the four diagnostic groups



* There was no variation in the BBS scores of the typically developing subjects

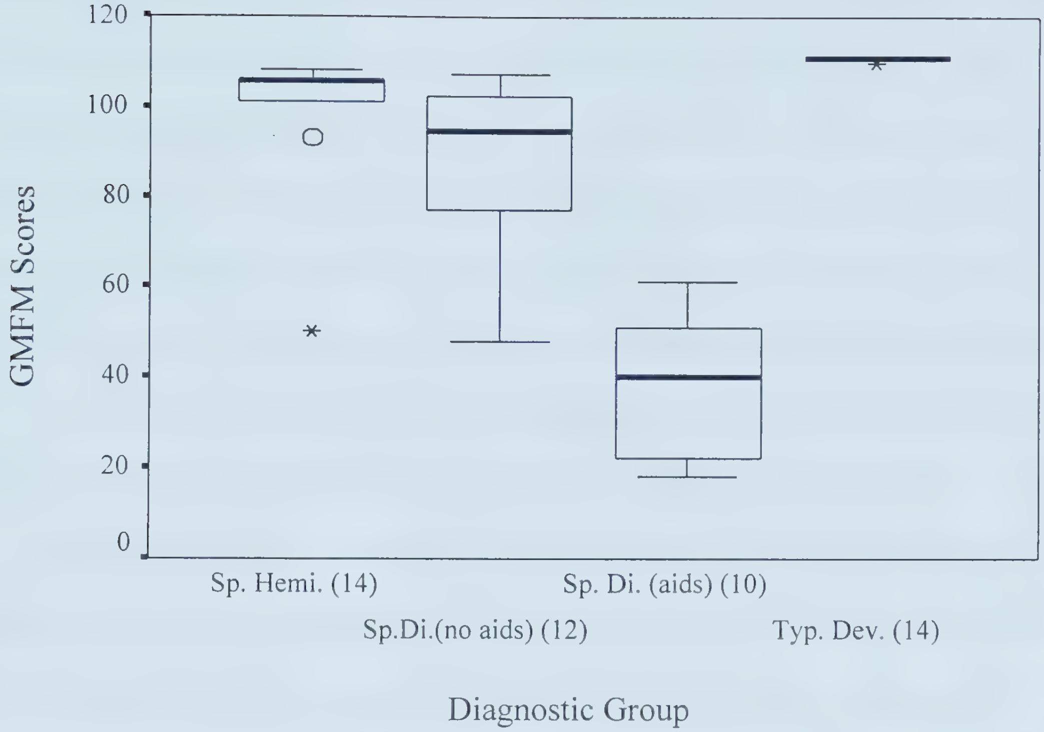


Figure 4.2 Box and whisker plots of GMFM scores of the four diagnostic groups

The range of variance across the four groups is apparent. The standard deviation of group 4 (typically developing children) is quite small for both tests while the standard deviation of group 3 (spastic diplegic children who use aids) for both tests was comparatively large. To examine this apparent difference more closely, two further tests were performed on the data. First, a measure of skewness was calculated for both the BBS scores and the GMFM scores. The measure of skewness for BBS scores was –1.71, indicating a strong negatively skewed distribution of scores (Glass & Hopkins, 1996). The measure of skewness for GMFM scores was –1.19, also indicating a negatively skewed distribution. Negatively skewed data indicates that the majority of the scores in the data set are clustered in the higher scores, with the tail of the distribution curve towards the lower scores (Glass & Hopkins, 1996). Second,

a test for the homogeneity of variance for both BBS and GMFM scores was performed. Both were significant, indicating that the variances in the sample groups were not equal. The underlying assumptions of an ANOVA are that the populations from which the samples are taken are normally distributed, and that the variances of the samples are relatively equal (Pagano, 1986). Both these assumptions were violated with this particular sample. The ANOVA, however, is robust enough to withstand these violations given that the cell sizes are close in size (Portney & Watkins, 1993). As the sample sizes of the diagnostic groups were similar, there was no need to further analyze the data using non-parametric statistics.

Examination of the box-and-whisker plots for both BBS scores and GMFM scores revealed one significant outlier in the group of children with spastic hemiplegia (#35). The data was reanalyzed without the scores for subject 35. Results indicated no change in the discriminative abilities of the BBS. Without the outlier, the discriminative abilities of the GMFM did change. Scores on the GMFM discriminated between the group children with spastic hemiplegia and the group of children with spastic diplegia who did not use aids to ambulate. This discrimination was not apparent when the outlier was included in the data analysis.

Classification concerns and further analyses

A more serious concern was that the traditional classification of children with CP by diagnosis might not provide an accurate description of the child's functional abilities. A review of all the children's charts confirmed that there was a range of functional abilities in one diagnostic group, the children with spastic diplegia who ambulated without aids. For example, subject 13 did not wear any orthotics, and participated in fastball, soccer and floor hockey, and did not use the handrail to ascend stairs. In contrast, subject 19 was not as active

in extra-curricular sports, required orthotic devices, and could not ascend stairs without the use of a handrail. Because of concerns that traditional diagnostic categories do not capture similar functional abilities, the children in the study were re-classified using the Gross Motor Function Classification System for CP (GMFCS) (Palisano et al., 1997) (Appendix G). The GMFCS provides clinicians with an alternative method of classifying children with CP. The GMFCS was developed using a Delphi consensus method (Palisano et al., 1997). The overall level of chance-corrected agreement was $\kappa = .75$. The five levels of classification represent meaningful distinctions in motor function, and are based on self-initiated movement (Palisano et al., 1997). The five classes are on an ordinal level. Level I represents children who move without restriction, and only have limitations in advanced skills, while Level V represents children with severe movement restrictions. Because of the motor abilities of the children in the study, only levels I through III were used. A chart review, looking specifically for information on functional abilities and involvement in extra-curricular sports activities, was used to reclassify the children. In cases where sufficient information could not be found on the chart, or it was unclear whether a child should be classified into Level I or II, items 84 and 85 on the GMFM were used to ascertain the child's stair climbing abilities. The investigator did not know the children's BBS and GMFM scores prior to reclassification. Table 4.7 describes all the children in the study, their diagnostic category, and their new classification using the GMFCS.

Table 4.7 Diagnostic categories and GMFCS classification of all subjects

No.	Clinical Diagnosis	GMFC Level	No.	Clinical Diagnosis	GMFC Level
012	Sp. Diplegia (aids)	III	049	Spastic Hemiplegia	I
004	Sp. Diplegia (aids)	III	046	Spastic Hemiplegia	I
007	Sp. Diplegia (aids)	III	025	Spastic Hemiplegia	I
014	Sp. Diplegia (aids)	III	032	Spastic Hemiplegia	I
015	Sp. Diplegia (aids)	III	022	Spastic Hemiplegia	I
017	Sp. Diplegia (aids)	III	024	Spastic Hemiplegia	I
018	Sp. Diplegia (aids)	III			
031	Sp. Diplegia (aids)	III			
044	Sp. Diplegia (aids)	III			
050	Sp. Diplegia (aids)	III			
003	Sp.Diplegia (no aids)	II			
009	Sp.Diplegia (no aids)	I			
011	Sp.Diplegia (no aids)	I			
013	Sp.Diplegia (no aids)	I			
019	Sp.Diplegia (no aids)	II			
021	Sp.Diplegia (no aids)	I			
023	Sp.Diplegia (no aids)	I			
030	Sp.Diplegia (no aids)	II			
033	Sp.Diplegia (no aids)	I			
034	Sp.Diplegia (no aids)	I			
035	Sp.Diplegia (no aids)	II			
045	Sp.Diplegia (no aids)	II			
001	Spastic Hemiplegia	I			
002	Spastic Hemiplegia	I			
005	Spastic Hemiplegia	I			
006	Spastic Hemiplegia	I			
008	Spastic Hemiplegia	I			
010	Spastic Hemiplegia	I			
016	Spastic Hemiplegia	II			
020	Spastic Hemiplegia	I			

All except one child with a diagnosis of spastic hemiplegia was classified in Level I on the GMFCS. All children with a diagnosis of spastic diplegia who used aids to ambulate were classified in Level III because of their gross motor abilities and their reliance on an

ambulatory aid. Of the 12 children with a diagnosis of spastic diplegia who did not use aids to ambulate, seven were classified in Level I, and the remaining five were classified in Level II. The main distinction between Level I and Level II is that children classified in Level II have limitations walking on uneven surfaces and inclines, and require a handrail to ascend and descend stairs (Palisano et al., 1997). The GMFCS is not appropriate for children with typical motor development. For the purposes of this study, typically developing children were arbitrarily classified as Level IV, although this does not correspond with Level IV on the GMFCS. The sample descriptives after re-classification can be found in Table 4.8.

Table 4.8 Sample Descriptives using the GMFCS

	BBS score (max = 56)		GMFM raw score (max = 111)	
GMFCS Level	Mean	SD	Mean	SD
I (n=20)	54.40	1.90	102.85	4.92
II (n=6)	42.33	8.76	68.00	18.25
III (n=10)	25.10	12.37	37.60	16.18
IV (n=14)*	55.86	0.36	110.93	0.27
Total Group (n=50)	47.50	13.51	87.88	29.98

* This is not Level IV on the GMFCS

The ANOVAs for both the BBS and GMFM scores were re-run using the re-classification. The results of the ANOVA for BBS scores are found in Table 4.9, the ANOVA for the GMFM scores in Table 4.10. Both ANOVAs were significant. Post-hoc analysis for the BBS revealed significant pair-wise differences among all groups of children except between children with spastic hemiplegia and typically developing children (Table 4.11).

Post-hoc analysis performed for the GMFM also revealed significant difference among all groups of children except children with spastic hemiplegia and typically developing children (Table 4.12). Box and whisker plots in figures 4.3 and 4.4 illustrate the BBS and GMFM findings after reclassification of the groups using the GMFCS.

Table 4.9 ANOVA results for BBS scores using GMFCS levels

	Sum of Squares	df	Mean Square	F	Significance
Between Groups	7107.75	3	2369.25	59.53	$p < .01$
Within Groups	1830.75	46	39.80		
Total	8938.50	49			

Table 4.10 ANOVA results for GMFM scores using GMFCS levels

	Sum of Squares	df	Mean Square	F	Significance
Between Groups	39571.40	3	13190.47	135.32	$p < .01$
Within Groups	4483.88	46	97.48		
Total	44055.28	49			

Table 4.11 Post-hoc Tukey HSD for BBS scores

Mean Difference				
Level/Level	I	II	III	IV
I	-	12.07 p = .001	29.30 $p \leq .001$	-1.46 p = .91
II		-	17.23 $p \leq .001$	-13.52 $p \leq .001$
III			-	-30.76 $p \leq .001$
IV				-

Table 4.12 Post-hoc Tukey HSD for GMFM scores

Mean Difference				
Level/Level	I	II	III	IV
I	-	34.85 p = .001	65.25 $p \leq .001$	-8.08 p = .10
II		-	30.40 $p \leq .001$	-42.93 $p \leq .001$
III			-	-73.33 $p \leq .001$
IV				-

Although significant differences were found with post-hoc analysis, there were further concerns with violations of the assumptions underlying the ANOVA analysis. Not

only was the data negatively skewed, and did not have homogeneity of variance, but the cell sizes were also unequal, with cell sizes ranging from 6 to 20. Two strategies were used to confirm the results from the ANOVA calculations. First, a t-test was performed between the two groups with relatively equal cell size, levels II (n=6) and III (n=10). This test was significant at an alpha level of .05. The test for homogeneity of variance was calculated for these two groups and indicated that the two groups did not have significantly different variances. These results supported the findings of the ANOVA calculation using the GMFCS classification. Second, a non-parametric analysis of variance was conducted on the data from the four new classification groups. The results of the Kruskal-Wallis test revealed a significant difference on both the BBS and GMFM scores among the groups.

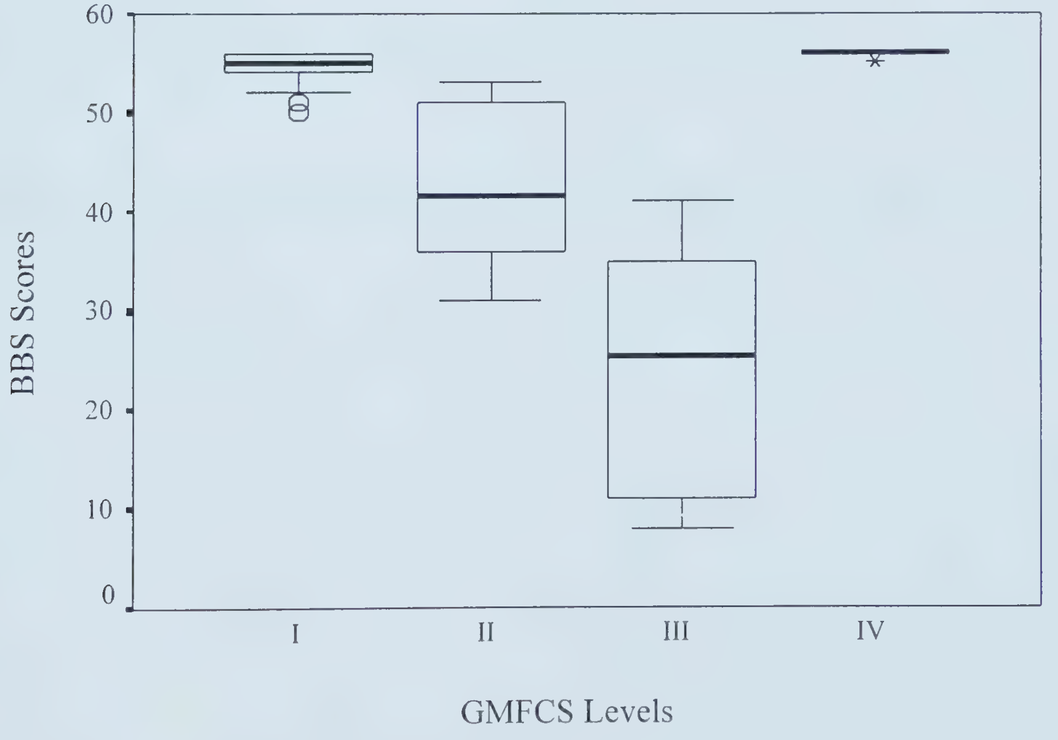


Figure 4.3 Box and whisker plots of BBS scores using the GMFCS classification

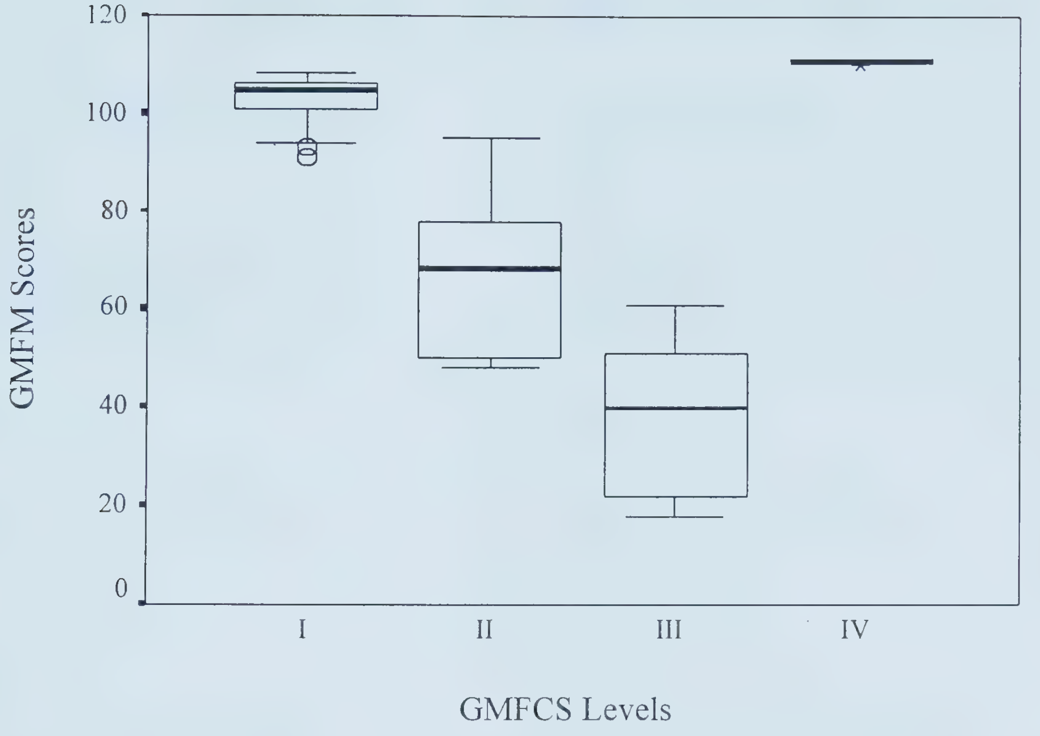


Figure 4.4 Box and whisker plots of GMFM scores using the GMFCS classification

A summary of the results used to evaluate discriminative abilities is found in Table 4.13.

Table 4.13 Summary of results of discriminative abilities of BBS and GMFM

Traditional Diagnostic Categories

Groups:

1 Spastic Hemiplegic (n=14)
2 Spastic Diplegic, no aids (n=12)
3 Spastic Diplegic, aids (n=10)
4 Typically Developing (n=14)

ANOVA results

BBS: significant ($p \leq .05$)
GMFM: significant ($p \leq .05$)

Post-hoc analyses

BBS

Group	1	2	3	4
1	-	n/s	*	n/s
2		-	*	n/s
3			-	*
4				-

GMFM

Group	1	2	3	4
1	-	n/s	*	n/s
2		-	*	*
3			-	*
4				-

* Indicates a significant difference

GMFM (without outlier)

Group	1	2	3	4
1	-	*	*	n/s
2		-	*	*
3			-	*
4				-

* Indicates a significant difference

GMFCS Classification

Groups:

Level I (n=20)
Level II (n=6)
Level III (n=10)
Level IV (n=14) *typically developing

ANOVA results

BBS: significant ($p \leq .05$)
GMFM: significant ($p \leq .05$)

Post-hoc analyses

BBS

Level	I	II	III	IV
I	-	*	*	n/s
II		-	*	*
III			-	*
IV				-

GMFM

Level	I	II	III	IV
I	-	*	*	n/s
II		-	*	*
III			-	*
IV				-

* Indicates a significant difference

Non-parametric (Kruskal-Wallis)

GMFM: significant ($p \leq .05$)
BBS: significant ($p \leq .05$)

Evaluation of correlation between BBS and GMFM scores

The correlation coefficients between BBS scores and GMFM scores for the three diagnostic CP groups were high (Table 4.14). The typically developing children did not have adequate variability in their BBS and GMFM scores, and as a result, the correlation appears very small. Correlations were calculated for the sample as a whole, as well as for the individual diagnostic groups. All correlations within the diagnostic groups were significant at $p \leq .01$.

Table 4.14 Pearson correlation between BBS and GMFM scores with diagnostic groups

Group	N	Pearson Correlation Coefficient (r)
All subjects	50	.96
Spastic Hemiplegia	14	.99
Spastic Diplegia (no aids)	12	.95
Spastic Diplegia (with aids)	10	.84
Typically Developing	14	-.11*

* Lack of variability in this group's scores on both the BBS and the GMFM

Pearson product moment correlation coefficients were also calculated once the data was reclassified using the GMFCS. The results are found in Table 4.15. The correlations between levels I, II and III were also high, and were significant at $p \leq .05$.

Table 4.15 Pearson correlation between BBS and GMFM scores after reclassification

GMFCS Group	N	Pearson Correlation Coefficient (r)
I	20	.83
II	6	.93
III	10	.84
IV	14	-.11*

* Lack of variability in this group's scores on both the BBS and the GMFM

CHAPTER 5

DISCUSSION

Discriminatory Abilities

Summary of results

The primary objective of this study was to investigate the discriminative abilities of the BBS when used with a population of ambulatory children with CP and typically developing children. The results of the discriminative abilities of the BBS in this study did not support the hypothesis that the four diagnostic groups would fall into a hierarchy based on their balance skills, as only the group who used aids was significantly different from the other groups. The discriminative ability of the GMFM was only marginally better than that of the BBS among the four diagnostic groups. There are two possible explanations for these findings. First, the BBS may not be a discriminative test when used with a pediatric population. The second possible explanation is that the four diagnostic groups were not as distinct as initially assumed in terms of their balance abilities. In order to tease out the effects of the two possible explanations, the children in the study were re-classified using a measure focused on function, the GMFCS. The results following reclassification showed improved discriminatory abilities of the BBS and the GMFM (Tables 4.11 and 4.12). There was still no discrimination between typically developing children and children in Level I on either test. Through consideration of these results, it appears that both test properties and classification issues affect the discriminatory abilities of the BBS. These issues will be discussed separately.

Test Characteristics of the BBS

Test characteristics seem to be one factor in the discriminatory abilities of the BBS. When using diagnostic categories, scores on the BBS did not discriminate between typically developing children and children with spastic hemiplegia, typically developing children and children with spastic diplegia who did not use aids, and also between children with spastic hemiplegia and children with spastic diplegia who did not use aids. After the children were reclassified using the GMFCS, the scores on the BBS discriminated among all the groups of children, except between typically developing children and children in Level I. Children in Level I included 13 of the 14 children with spastic hemiplegia, and 7 of the 12 children with spastic diplegia who did not use aids to ambulate. The fact that Level I included children from two diagnostic groups suggests similar functional abilities in children across these two diagnoses. A child in Level I "walks without restrictions [but has] limitations in more advanced gross motor skills" (Palisano et al., 1997), indicating a high level of function.

The most probable reason for the lack of discrimination in BBS scores between typically developing children and children with high functional abilities in either classification scheme is a ceiling effect. While typically developing children would be expected to attain perfect scores on the BBS, the items may also not have been challenging enough to capture the higher-level balance deficits in children with a mild motor impairment. The most challenging items on the BBS include such items as reaching forward with an outstretched arm (#8), turning in a full circle in both directions (#11), alternately lifting each foot to touch a stool (#12), standing in tandem stance (#13) and standing on one leg (#14). During the initial development of the BBS, Berg (1989) stated that, " the lack of an item that requires a postural response to an external stimulus or uneven support surface…will likely limit the utility of the scale when assessing very

active persons with minimal deficits" (Berg et al., 1989). The scores obtained by typically developing children, children with spastic hemiplegia, and children in Level I of the GMFCS on the BBS are all quite high. .Scores for typically developing children, children with spastic hemiplegia, and children in Level I were all within 2.8 points of the maximum. These high scores indicate that the items were not difficult enough to discriminate between these groups if indeed they do differ on balance abilities. Investigators examining postural responses of young, elderly, and elderly subjects with hemiplegia also concluded that the BBS may have limited discriminative abilities among subjects at the high end of the scale (Garland, Stevenson, & Ivanova, 1997).

The lack of discrimination between typically developing children and children with spastic hemiplegia was further compounded by the method of administration of the BBS. The BBS does not specify which side the subject must use when performing items such as single leg stance. Thus, the children with spastic hemiplegia were able to use their non-involved side to perform these activities. This may have further masked their balance deficits, hence the lack of discrimination in BBS scores.

The BBS scores also did not discriminate between children with spastic hemiplegia and children with spastic diplegia who did not use ambulatory aids. This latter group was quite variable in their functional abilities, and some children received very high scores on the BBS. Nine out of 12 children in this group had BBS scores ranging from 51 to 56 out of 56. The scores were likely affected by the ceiling effect of the BBS. The variability of scores of children with spastic diplegia who walked without aids was evident upon reclassification, when 7 of the 12 children were classified in Level I, with most of the children with spastic hemiplegia. The significant variability of this group can also account for the lack of discrimination between their scores and the scores of typically developing children.

The BBS scores discriminated among the group of children with spastic diplegia who did use aids and all other children. There is a significant drop in functional abilities between children with spastic diplegia who use aids and those who do not. The children with spastic diplegia who used aids were all reclassified into Level III. Aside from the use of an ambulatory aid when walking indoors and outdoors, children in Level III may also use a manual wheelchair for long distances, where children in Level II do not (Palisano et al., 1997). This large difference in functional abilities resulted in significantly different scores on the BBS. Unlike the other diagnostic or GMFCS groups, the group of children with spastic diplegia who used aids did not show a ceiling effect. Due to the nature of the test items, the results of this study suggest that the BBS is not an appropriate tool to use to assess balance deficits in high functioning children with CP, regardless of their diagnosis. However, it may be an appropriate tool for children who use aids to ambulate.

<u>Test characteristics of the GMFM</u>

The GMFM was slightly better in discriminating among diagnostic groups than the BBS. Like the BBS, the GMFM discriminated among the children with spastic diplegia who used aids to ambulate and all other groups. Unlike the BBS, the scores on the GMFM also discriminated among the children with spastic diplegia who did not use aids, and typically developing children. There was still no discrimination between the mean scores achieved by the group of children with spastic hemiplegia and the group of typically developing children, or between the children with spastic hemiplegia and the children with spastic diplegia who did not use aids. When the children were reclassified, the discriminatory abilities of the GMFM were the same as that of the BBS. The GMFM scores discriminated among children at all levels, except between children in Level I and typically developing children.

The GMFM does not exclusively test balance, and some items in the last dimension of the GMFM are more difficult than those found in the BBS. The more difficult items in the GMFM test other skills in addition to balance that are required in movement. These include stepping over a bar, ascending and descending stairs, getting to standing from the floor, and hopping on one leg (Russell et al., 1993). These skills are influenced by attributes of movement besides balance, such as timing, coordination, and strength. When these characteristics of movement are impaired, Campbell (1991) describes them as the "negative symptoms" of CP. She indicates that "inadequate force production, delayed initiation of movement, and inappropriate postural set" may significantly impact motor dysfunction in children with CP (Campbell, 1991, p.6). Despite the inclusion of more challenging items on the scale, the GMFM still appears to have a ceiling effect when used with very high-functioning children with CP, such as those with spastic hemiplegia. Children with spastic hemiplegia do have some "negative symptoms", but they have one relatively un-involved side. They can use this un-involved side to gain momentum and propulsion for more difficult gross motor tasks that may require force and timing. The scores achieved by typically developing children, children with spastic hemiplegia and children in Level 1 on the GMFM were all quite high. Typically developing children were at the maximum score of 111 while children with spastic hemiplegia and children in Level I were 11 points and 8 points below, respectively. These extremely high scores again indicate that the items on the GMFM were not difficult enough to discriminate among these groups.

Children with spastic diplegia who did not use aids were also affected by this ceiling effect, hence the lack of discrimination between their scores and the scores of children with spastic hemiplegia. As discussed previously, the group of children with spastic diplegia who did not use aids was very heterogeneous in their functional abilities, and some children had very high scores on the GMFM, similar to children with spastic hemiplegia. There were five children in

this group who received scores ranging from 101 to 107 out of 111 on the GMFM. And as previously discussed, 7 of the 12 children in this group were reclassified into Level I on the GMFCS. Therefore this group, too, was affected by the ceiling effect on the GMFM.

When the outlier was removed from the data, the GMFM did discriminate between the group of children with spastic hemiplegia and the group of children with spastic diplegia who walked without aids. The instability of the GMFM scores of this group is a reflection of the small sample size. When chart reviews were undertaken, it was determined that subject 35 (the outlier) should not have been excluded from the study. Although he was a non-verbal communicator, he was not the only subject with a speech and language deficit. His diagnosis was that of spastic hemiplegia, but his functional abilities were quite different than the other subjects in the same diagnostic category. This was verified after reclassification, when he was the only child with a diagnosis of spastic hemiplegia who was placed in Level II. It is possible that a combination of cognitive and functional characteristics may have resulted in his extremely low scores on both the BBS and the GMFM. The GMFM may have slightly better discriminative abilities than the BBS when children are grouped according to diagnosis. But given that the sample sizes of each cell in this study were small, the results must be interpreted with caution. These results may be an artifact of sampling, rather than a true reflection of the tests themselves.

Unlike the BBS, the GMFM scores did discriminate between the group of typically developing children and the group of children with spastic diplegia who did not use aids to ambulate. This improved discrimination of GMFM scores was likely a result of children with spastic diplegia who did not use aids being more affected by the "negative symptoms" of CP. Items such as stepping over a bar held at knee level, tandem walking on a narrow line, hopping on one leg in a confined space, and ascending and descending stairs (Russell et al., 1993) likely

posed a bigger challenge for children with spastic diplegia who did not use aids to ambulate than for children with spastic hemiplegia, or typically developing children.

The significant drop in function of the children with spastic diplegia who used aids compared to all other children in the study can explain the ability of the GMFM scores to discriminate between this group and all others. Children who used aids to ambulate were not permitted to use these aids when performing the GMFM. Thus the more difficult items in Dimension E, and some items in Dimension D posed a significant challenge to these children. Children with spastic diplegia who use aids likely also exhibit many "negative symptoms", and are more influenced by difficulties in timing, coordination, strength and excessive muscle tone. The results also reveal that a wide gap in functional abilities exists between children with spastic diplegia who used aids to ambulate, and both children in the same diagnostic category who did not use aids, and children with spastic hemiplegia. The change in function is not linear among the groups as inferred by the hierarchy of balance skills in the stated hypothesis. Instead, children with spastic hemiplegia and approximately half the children with spastic diplegia who walked without aids are similar in their motor skills, followed by the remaining children with spastic diplegia who walked without aids, and finally, children with spastic diplegia who required aids.

In conclusion, neither the BBS or the GMFM are adequate tests to measure balance deficits in children with mild functional limitations. This finding suggests that alternative measures such as the Bruininks-Oseretsky Test of Motor Proficiency (Bruininks, 1978) should be considered for use with this population. The results also indicate that classification issues clearly affect the discriminative abilities of the BBS and the GMFM.

Reclassification of the subjects

A major finding of this study is that the reclassification of the children with CP using the GMFCS improved the discriminatory abilities of both the BBS and the GMFM. Following reclassification, the BBS and the GMFM discriminated among all groups except between children in Level I and typically developing children. The lack of discrimination between typically developing children and children in Level I can be explained by the ceiling effect of both the BBS and the GMFM. The most significant change occurred in the group of children with spastic diplegia who ambulated without aids. Of the twelve children in this group, seven were reclassified as Level I, and the other five were reclassified as Level II. Of the 14 children with a diagnosis of spastic hemiplegia, only one was reclassified as Level II, while the rest were in Level I. All the children with spastic diplegia who use aids to ambulate were reclassified as Level III. The high degree of variance in the group of children with spastic diplegia who did not use aids was apparent upon further investigation of their functional abilities. For example, subject 13 plays soccer, fastball and hockey, and ambulated independently at 24 months. In contrast, subject 30 does not participate in any extra-curricular sports activities, and did not ambulate independently until the age of five. This finding suggests that the traditional classification of CP by tonus and distribution provides an inaccurate reflection of a child's functional abilities.

The classification of CP has been discussed for many years. Sachs and Petersen developed the first classification scheme for CP in 1890 (Ingram, 1984). Since then, several different methods of classification have been developed. The system developed by Fay (1950) is based on the specific location of the neurological lesion, impairments in tone, reflexes and voluntary control of movement. Another system is similar to that developed by Fay (Perlstein, 1952). Minear's system of classification (1956) was also based on the location of the

neurological insult, like Fay's and Perlstein's, but also included the parts of the body involved, and the degree of motor impairment. Balf and Ingram (1955) developed a system similar to Minear (1956), but did not include the anatomical location of the insult. More recent classification schemes have included ambulatory status as well as degree of impairment (Badell-Ribera, 1985; Yokochi, Shimabukoro, Kodama, & Hosoe, 1993). These methods are useful in describing the impairment, but lack any mention of the child's functional status. Traditional classification provides no indication of the child's gross motor abilities, except that it is assumed that the more severe the impairment, the more limited the child's function.

Classification schemes based more on function than on impairment in CP have only recently been developed. Bleck (1987) developed a system with seven dimensions. These include: 1) independent community walking; 2) community walking with devices; 3) household walking, requiring a wheelchair outside the home; 4) exercise walking only requiring aids or assistance; 5) wheelchair use (independent mobility and transfers); 6) wheelchair use (dependent for mobility and transfers); and 7) lack of sitting balance and dependent for wheelchair mobility (Bleck, 1987). This classification scheme is thought to be useful when identifying orthopaedic goals for children with CP (Msall, Rogers, Ripstein, Lyon, & Wilczenski, 1997). The Gross Motor Function Classification System developed by Palisano et al. (1997) is a major departure of philosophy in the classification of children with CP. This classification scheme is based on self-initiated movements, emphasizing sitting and walking (Palisano et al., 1997). The system includes descriptors of function at various ages, and children can change from one functional level to another as they mature. The classification scheme can be used with children from birth to twelve years of age. Children with minimal functional restrictions are classified in Level I, while children with the most functional restrictions are classified in Level V.

Classification is also an issue in the arena of sports and physical education. Athletes with CP were classified according to diagnosis in the early days of disabled sports. Athletes with CP are now classified according to functional abilities, and grouped into one of eight levels (Nearingburg, 1999). Work is currently underway to re-evaluate this method of classification, and some controversy exists about whether the current functional classification is the most effective for competitive athletes with CP (Nearingburg, 1999). The results from this study indicate that classification based on function, rather than diagnostic groups, may produce subgroups that are more similar in their abilities than traditional classification by tonus and body distribution.

In conclusion, both test characteristics and issues of classification affect the discriminatory abilities of the BBS and the GMFM. Test characteristics affect children with high gross motor function, as there is a ceiling effect when used with this population. Classification issues affect the scores achieved by a group of children with heterogeneous functional abilities. The reclassification in this study served to better sort out the group of children with spastic diplegia that did not use aids. Both test characteristics and classification issues, in terms of the children with spastic diplegia who ambulate independently, affected the discriminative abilities of the BBS and the GMFM. The conclusions drawn from the analysis of discriminative abilities of the BBS and the GMFM can be found in Table 5.1. The results of the discriminative analysis suggest that the issues of classification must be examined more closely. The time may have come to make functional classification the rule rather than the exception in a population of children with CP.

Table 5.1 Issues affecting discriminative abilities of the BBS and the GMFM

Test Characteristics	**Classification Issues**
Ceiling effect when used with children with spastic hemiplegia	Heterogeneous functional abilities of children with a diagnosis of spastic hemiplegia and spastic diplegia who walk independently
Discriminative abilities with children with spastic diplegia who walk independently are influenced by both test characteristics and classification issues	

Correlation between BBS scores and GMFM scores

The secondary objective of this study was to examine the relationship of BBS scores with GMFM scores. The relationship was hypothesized to be moderate at best ($r = .40 - .60$) because it was assumed that balance is only one aspect of overall gross motor function measured by the GMFM. The results of the analysis failed to support this hypothesis. The scores on the BBS and the GMFM for all diagnostic groups, as well as the group as a whole, were very highly correlated. Following reclassification using the GMFCS, the correlations remained high. The most likely explanation for the high correlations among the BBS and GMFM scores is that the BBS measures more than just balance. Items such as moving from sit to stand, and picking an object off the floor require not just balance, but strength, coordination and timing of movement. Assuming that laboratory tools measure "pure" balance, the poor correlation of the BBS to laboratory measures of balance suggests that the BBS does not measure just balance, rather a combination of gross motor skills that contribute to postural control. The GMFM was designed to measure motor function. As such, the items on the GMFM also measure aspects of gross motor function such as strength, balance, and coordination. Thus, the correlation between scores on the BBS and the GMFM were higher than hypothesized. Outside the laboratory, few clinical

measures exist that examine strictly balance. The Clinical Test of Sensory Interaction for Balance test (Shumway-Cook & Horak, 1986) is one example of a clinical tool that is specific to balance. This test measures the degree of sway experienced upon alteration of sensory inputs. It is difficult to isolate balance from other motor skills when assessing tasks such as those found on the BBS.

The BBS- a measure of functional balance?

Is the BBS a measure of functional balance in children with CP? The items on the BBS measure balance deficits on two levels. First, they examine balance at the level of impairment, in items such as standing with feet together, or standing with eyes closed. Items on the BBS also measure balance at the level of activity, with items such as picking up an object on the floor, or turning to look over one shoulder. It can be argued that some items on the BBS are "functional" (e.g. picking up an item off the floor), and others certainly assess components of functional tasks (e.g. alternating placing the foot on a stool). However, a functional assessment of balance needs to examine the interaction between the person, the task and the environment in terms of balance (Law et al., 1998). The BBS does examine balance abilities, and some items examine certain functional motor tasks, such as moving from sitting to standing. It does not, however, focus on the environment, or the interaction of all three factors. For example, the BBS does not examine the effect of changing the environment or the task itself on the ability of the subject to reach the task goal.

Current theoretical models in rehabilitation literature are based on the interaction of person, task and environment in terms of both assessment and treatment. The Person-Occupation-Environment Model (POE) considers the person, his/her environment and activities, or occupations, interacting over time (Strong et al., 1999). The performance of an activity is

determined by the dynamic interactions of all three factors in the model (Strong et al., 1999). Similarly, ecological task analysis considers the person, the task goal, and the environment as part of one system (Davis & Burton, 1991). The systems theory too advocates that a child's performance of a functional task is dependent on the child him/herself, the environment in which the task is performed, and the characteristics of the task itself (Law et al., 1998). Current neuroscience research has also found that the environment plays a significant role in balance and postural control (Sveistrup & Woollacott, 1993). Theories such as ecological task analysis and the dynamic systems theory extend not only to assessment, but serve to guide approaches to treatment as well. Davis and Burton (1991) emphasize that the task goal must remain consistent throughout assessment and intervention.

Theory must guide not only approaches to assessment and intervention, but must play a role in the outcome measures used to evaluate the efficacy of the intervention that is provided. If an outcome measure for balance is to measure balance in a functional context, then it should evaluate the *interaction* of person, task and environment, rather than each component individually. To date, no single outcome measure can fulfill this role alone. The BBS has potential to be used to assess specific areas of balance impairments. If a dynamic systems based assessment of a child with CP identifies a deficit in balance that is measured by the BBS, then the BBS may be an appropriate tool for evaluation and measuring the outcome of the intervention. The BBS must be used in the correct context, keeping in mind the limitations of the tool.

Limitations of the study

The primary limitation of this study is the small sample size. Small samples may not reflect the true inherent variability of each group. This was apparent when an outlier was found in the diagnostic group of children with spastic hemiplegia. If a larger sample had been used for

the study, this group may have been more heterogeneous, and the subject may not have been an outlier at all. The same holds true for all other diagnostic groups in this study. Larger sample sizes may have resulted in great heterogeneity of all three diagnostic groups.

The second limitation of the study was that the BBS was used under the preset administration guidelines used for a population of adult clients. These guidelines may not have been entirely appropriate for a population of children with CP, and may have required modification.

The generalizability of the results of this study is limited to a population of ambulatory children with CP between the ages of eight and twelve with a diagnosis of spastic hemiplegia or spastic diplegia.

Clinical Implications

This is the first study that has examined the use of the BBS in a population of children with CP. While laboratory measures exist to measure balance deficits, there are currently no tools available for use by clinicians to measure balance in children that have been well validated.

The BBS does have some distinct clinical advantages. First, it is short, and therefore relatively easy to administer in a clinical setting. The average time to administer the BBS in this study was 10 to 12 minutes. It requires little equipment, and does not require intensive training on the part of the clinician to use it effectively. Most children understood the instructions, and were able to attempt all the items. Given that it is already an established and accepted measure of functional balance in adults, it seems reasonable that it can be used to assess balance in children as well. One of the drawbacks of using the BBS in a population of children with CP is the numerous items that require the maintenance of a static position for a set period of time. Some of the children in this study did not complete several timed items due to boredom. They were

physically capable of completing the items, but could not sustain the interest to complete them. Distractibility was also a difficulty encountered with some children.

The BBS should not be used with children who have minimal motor deficits, or mild balance impairments. The results of this study have demonstrated a definite ceiling effect when the BBS is used with this population of children. At this stage, the BBS is not an appropriate tool to evaluate change over time in balance skills, especially with high-functioning children. Given that balance does not mature in children until the age of seven, the BBS should not be used with children younger than seven or eight years of age. Balance deficits detected in younger children may just be an indication of maturing balance, as opposed to true balance deficits. Although the BBS would not be an appropriate tool to use with children who were not ambulatory, it has potential to be used with ambulatory children with a diagnosis of CP with moderate balance impairments.

Future research considerations

Future research should be conducted to examine the utility of the BBS as an evaluative tool to measure change in balance abilities over time with a specific group of children with CP. Further studies could also evaluate the discriminatory abilities of the BBS if children were required to use their non-dominant leg for single stance activities, especially in children with spastic hemiplegia.

Summary

This study examined the discriminative abilities of the BBS in a population of ambulatory children with a diagnosis of CP between the ages of eight and twelve. The study also

examined the relationship between the BBS and the GMFM. A total of 50 children participated in the study. Thirty-six children had a diagnosis of CP, and the other 14 had typical motor abilities. Subjects were tested on both the BBS and dimensions D and E of the GMFM.

The BBS did not discriminate as well as expected among the four diagnostic groups of children in the study. The discriminative ability of the GMFM among the four diagnostic groups was marginally better. When the children were reclassified using the GMFCS, the discriminatory abilities of both the BBS and the GMFM improved. Both tools demonstrated a ceiling effect if used with children who had mild balance impairments. The relationship between the BBS and the GMFM was very high.

Conclusions

1. Traditional categorization by diagnosis does not adequately reflect functional abilities of children with CP, especially children with spastic diplegia who ambulate without aids. Functional classification using the GMFCS provided a more accurate reflection of functional balance abilities, and resulted in improved discriminatory abilities of the BBS.
2. The BBS is not an appropriate tool for use with children with minimal balance impairments.
3. The relationship of scores between the BBS and the GMFM was very high, indicating that the BBS may measure factors other than purely balance.

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APPENDIX A:

THE BERG BALANCE SCALE

BERG BALANCE SCALE WORKSHEET

	Date			
Item	**Description**	**Score**	**Score**	**Score**
1	sitting to standing			
2	standing unsupported			
3	sitting unsupported			
4	standing to sitting			
5	transfers			
6	standing with eyes closed			
7	standing with feet together			
8	reaching forward with outstretched arm			
9	retrieving object from floor			
10	turning to look behind			
11	turning 360 degrees			
12	placing alternate foot on stool			
13	standing with one foot in front			
14	standing on one foot			
	TOTAL			

GENERAL INSTRUCTIONS

Please demonstrate each task and/or give instructions as written. When scoring, please record the lowest response category that applies for each item.

In most items, the subject is asked to maintain a given position for a specific time. Progressively more points are deducted if the time or distance requirements are not met, if the subject's performance warrants supervision, or if the subject touches an external support or receives assistance from the examiner. Subjects should understand that they must maintain their balance while attempting the tasks. The choices of which leg to stand on or how far to reach are left to the subject. Poor judgment will adversely influence the performance and the scoring.

Equipment required for the testing are a stopwatch or watch with a second hand, and a ruler or other indicator of 2, 5, and 10 inches. Chairs used during testing should be of reasonable height. Either a step or a stool (of average step height) may be used for item # 12.

1. SITTING TO STANDING
INSTRUCTIONS: Please stand up. Try not to use your hands for support.
( ) 4 able to stand without using hands and stabilize independently
( ) 3 able to stand independently using hands
( ) 2 able to stand using hands after several tries
( ) 1 needs minimal aid to stand or to stabilize
( ) 0 needs moderate or maximal assist to stand

2. STANDING UNSUPPORTED
INSTRUCTIONS: Please stand for 2 minutes without holding.
( ) 4 able to stand safely 2 minutes
( ) 3 able to stand 2 minutes with supervision
( ) 2 able to stand 30 seconds unsupported
( ) 1 needs several tries to stand 30 seconds unsupported
( ) 0 unable to stand 30 seconds unsupported
If a subject is able to stand 2 minutes unsupported, score full points for sitting unsupported. Proceed to item # 4.

3. SITTING WITH BACK UNSUPPORTED BUT FEET SUPPORTED ON FLOOR OR ON A STOOL
INSTRUCTIONS: Please sit with arms folded for 2 minutes.
( ) 4 able to sit safely and securely 2 minutes
( ) 3 able to sit 2 minutes under supervision
( ) 2 able to sit 30 seconds
( ) 1 able to sit 10 seconds
( ) 0 unable to sit without support 10 seconds

4. STANDING TO SITTING
INSTRUCTIONS: Please sit down.
( ) 4 sits safely with minimal use of hands
( ) 3 controls descent by using hands
( ) 2 uses back of legs against chair to control descent
( ) 1 sits independently but has uncontrolled descent
( ) 0 needs assistance to sit

5. TRANSFERS
INSTRUCTIONS: Arrange chair(s) for a pivot transfer. Ask subject to transfer one way toward a seat with armrests and one way toward a seat without armrests. You may use two chairs (one with and one without armrests) or a bed and a chair.
( ) 4 able to transfer safely with minor use of hands
( ) 3 able to transfer safely definite need of hands
( ) 2 able to transfer with verbal cueing and/or supervision
( ) 1 needs one person to assist
( ) 0 need two people to assist or supervise to be safe

6. STANDING UNSUPPORTED WITH EYES CLOSED
INSTRUCTIONS: Please close your eyes and stand still for 10 seconds.
( ) 4 able to stand 10 seconds safely
( ) 3 able to stand 10 seconds with supervision
( ) 2 able to stand 3 seconds
( ) 1 unable to keep eyes closed 3 seconds but stays steady
( ) 0 needs help to keep from falling

7. STANDING UNSUPPORTED WITH FEET TOGETHER
INSTRUCTIONS: Place your feet together and stand without holding.
( ) 4 able to place feet together independently and stand 1 minute safely
( ) 3 able to place feet together independently and stand for 1 minute with supervision
( ) 2 able to place feet together independently but unable to hold for 30 seconds
( ) 1 needs help to attain position but able to stand 15 seconds feet together
( ) 0 needs help to attain position and unable to hold for 15 seconds

8. REACHING FORWARD WITH OUTSTRETCHED ARM WHILE STANDING
INSTRUCTIONS: Lift arm 90°. Stretch out your fingers and reach forward as far as you can. (Examiner places a ruler at end of fingertips when arm in at 90°. Fingers should not touch the ruler while reaching forward. The recorded measure is the distance forward that the fingers reach while the subject is in the most forward lean position. When possible, ask subject to use both arms when reaching to avoid rotation of the trunk.)
( ) 4 can reach forward confidently > 10 inches
( ) 3 can reach forward > 5 inches safely
( ) 2 can reach forward > 2 inches safely
( ) 1 reaches forward but needs supervision
( ) 0 loses balance while trying/requires external support

9. PICK UP OBJECT FROM THE FLOOR FROM A STANDING POSITION
INSTRUCTIONS: Pick up the shoe/slipper which is placed in front of your feet.
( ) 4 able to pick up slipper safely and easily
( ) 3 able to pick up slipper but needs supervision
( ) 2 unable to pick up but reaches 1-2 inches from slipper and keeps balance independently
( ) 1 unable to pick up and needs supervision while trying
( ) 0 unable to try/needs assist to keep from losing balance or falling

10. TURNING TO LOOK BEHIND OVER LEFT AND RIGHT SHOULDERS WHILE STANDING
INSTRUCTIONS: Turn to look directly behind you over your left shoulder. Repeat to the right. Examiner may pick an object to look at directly behind the subject to encourage a better twist turn.
( ) 4 looks behind from both sides and weight shifts well
( ) 3 looks behind one side only other sides shows less weight shift
( ) 2 turns sideways only but maintains balance
( ) 1 needs supervision when turning

( ) 0 needs assistance while turning

11. TURNS 360 DEGREES
INSTRUCTIONS: Turn completely around in a full circle. Then turn a full circle in the other direction.
( ) 4 able to turn 360° safely in 4 seconds or less
( ) 3 able to turn 360° safely one side only in 4 seconds or less
( ) 2 able to turn 360° safely but slowly
( ) 1 needs close supervision or verbal cueing
( ) 0 needs assistance while turning

12. PLACING ALTERNATE FOOT ON THE STEP OR STOOL WHILE STANDING UNSUPPORTED
INSTRUCTIONS: Place each foot alternately on the step/stool. Continue until each foot has touched the step/stool 4 times.
( ) 4 able to stand independently and safely and complete 8 steps in 20 seconds
( ) 3 able to stand independently and complete 8 steps > 20 seconds
( ) 2 able to complete 4 steps without aid with supervision
( ) 1 able to complete > 2 steps needs minimal assist
( ) 0 needs assistance to keep from falling/unable to try

13. STANDING UNSUPPORTED ONE FOOT IN FRONT
INSTRUCTIONS: (DEMONSTRATE TO SUBJECT) Place one foot directly in front of the other. If you feel that you cannot place your foot directly in front try to step far enough ahead that the heel of your forward foot is ahead of the toes of the other foot. (To score 3 points, the length of the step should exceed the length of the other foot and the width of the stance should approximate the subject's normal stride width.)
( ) 4 able to place foot tandem independently and hold 30 seconds
( ) 3 able to place foot ahead of other independently and hold 30 seconds
( ) 2 able to take small step independently and hold 30 seconds
( ) 1 needs help to step but can hold 15 seconds
( ) 0 loses balance while stepping or standing

14. STANDING ON ONE LEG
INSTRUCTIONS: Stand on one leg as long as you can without holding.
( ) 4 able to lift leg independently and hold > 10 seconds
( ) 3 able to lift leg independently and hold 5 – 10 seconds
( ) 2 able to lift leg independently and hold = or > 3 seconds
( ) 1 tries to lift leg unable to hold 3 seconds but remains standing independently
( ) 0 unable to try or needs assist to prevent fall

( ) **TOTAL SCORE (Maximum 56)**

APPENDIX B:

SAMPLE SIZE CALCULATIONS

SAMPLE SIZE CALCULATIONS

Two sample size calculations were performed, as there were two objectives to the proposed study. The first objective was to assess the discriminative validity of the Berg Balance Scale. A one-way ANOVA was used to analyze the results. The sample size formula used is one when analyzing data using a t-test for means. This formula is accepted when using a one-way ANOVA (Kraemer & Thiemann, 1987, p.49). The sample size calculation is presented below. The mean Berg Balance Scale scores and standard deviation were taken from a validation study of the Berg Balance Scale in an elderly population (Berg et al., 1992b). Mean 1 (x_1) is the mean score on the Berg Balance Scale achieved by elderly subjects who did not use aids to ambulate. Mean 2 (x_2) is the mean score achieved on the Berg Balance Scale by elderly subjects who used a cane to ambulate indoors. Mean scores for elderly subjects were used in the sample size calculations, as there were no means found in the literature for children. The two groups of elderly subjects chosen were thought to most closely approximate children with spastic hemiplegia (mean 1) and children with spastic diplegia who use aids to ambulate (mean 2). The standard deviation is the average of the standard deviations found for the above two means.

$x_1 - x_2 / sd = \text{effect size}$

$49.6 - 45.3 / 4.5 = 0.96$

Based on a power of 80%, using a power table, the number of subjects required per group is **13**.

Sample size calculations for the second objective of the study- the concurrent validity of the Berg Balance Scale and the Gross Motor Function Measure were calculated using the

following formula and a master table for one-tailed test with an alpha level of 0.05 (Kraemer & Thiemann, 1987).

$\Delta = (p - p_o)(1 - p\,p_o)$ where p= expected correlation and p_o= the correlation that would occur by chance

$\Delta = (0.8 - 0.3)[1 - (0.8)(0.3)] = 0.38$

$n = v + 1$ $\quad\quad$ $n = 40 + 1 = \mathbf{41}$

According to the above sample size calculations, using a power of 80%, a total of **41** subjects are required for the study.

APPENDIX C:

LETTER OF INVITATION AND PAMPHLET

LETTER OF INVITATION

Dear :

I would like to invite you to take part in a research project to look at a new tool to measure balance in children with a diagnosis of cerebral palsy. This project is part of my Masters of Science in Physical Therapy program at the University of Alberta. I got your name from the records at the Glenrose Rehabilitation Hospital.

Forty-five children between the ages of 8 and 12 with a diagnosis of cerebral palsy are needed for this study. The study involves a 45-minute test session where you will have to complete two simple tests of balance. The testing sessions will take place at the Glenrose Rehabilitation Hospital. There are no risks to you by taking part in the study.

The people involved in this research study are named at the bottom of this letter. If I do not hear from you in two weeks, I will call you to see if you are interested in participating in the study.

Thank you for your interest. I hope that you will be able to take part in this study.

Yours sincerely,

Gayatri Kembhavi, B.Sc.P.T.
471-2262, ext. 2280

Researchers:

Gayatri Kembhavi, Masters Candidate, Department of Physical Therapy, Faculty of Rehabilitation Medicine, University of Alberta; Physical Therapist, Glenrose Rehabilitation Hospital

Dr. Johanna Darrah, Graduate Supervisor, Assistant Professor, Department of Physical Therapy, Faculty of Rehabilitation Medicine, University of Alberta

TEST YOUR BALANCE!!

Who are we?

Physical therapists interested in children and movement. We want to know if a test of balance used with adults can also be used with children.

What do you have to do?

Some quick and easy things like stand with your eyes closed, or pick something off the floor. It will only take 45 minutes.

Where do you have to go?

The Glenrose Hospital…just one time!

Why?

It will help us find a new way to measure balance in children, and besides, IT WILL BE FUN!!

APPENDIX D:

INFORMATION LETTER FOR PARENTS AND CHILDREN

INFORMATION LETTER FOR PARENTS AND CHILDREN

Title: The Berg Balance Scale: validation in a pediatric population

Investigators: Gayatri Kembhavi, Graduate Student
Department of Physical Therapy/ Glenrose Rehabilitation Hospital
471-2262, ext. 2280

Johanna Darrah, PhD
Graduate Supervisor, Department of Physical Therapy
492-9142

Purpose: The purpose of this study is to see if the Berg Balance Scale can be used with children to assess their balance.

Background: Children with cerebral palsy (CP) often have problems with balance. Physical therapists work on improving their balance. They need a test that can measure balance. The Berg Balance Scale has been used with adults, but not with children. This study will see if it can be used with children.

Procedures: Children without CP and children with CP with different balance abilities will be used for this study. Children will be tested using the Berg Balance Scale and part of the GMFM (Gross Motor Function Measure). Testing will take about 45 minutes, and take place at the Glenrose Rehabilitation Hospital. Each child will only have to do each test once. The children will be asked to do such things as pick up an object from the floor, stand with their eyes closed and walk a few steps. The testers will be physical therapists who work at the Glenrose Hospital. Information about the children's diagnosis, birth date, and whether or not they use walkers or crutches will be taken from their hospital chart.

Benefits/ Risks: This study will tell us if the Berg Balance Scale is a useful test to use with children with CP. There are no known risks to your child by participating in this study. Your parking or bus fare will be paid.

Confidentiality: Only the investigators will have access to the information gathered during this study. Names will not be put on any records, and no names will be used in any papers or publications. Data will be stored in a secure location for seven years. No other staff will have access to the information. All information will be held confidential except when professional codes of ethics and/or legislation require reporting. If any further analysis is conducted with the study, further ethics approval will be sought first.

Freedom to withdraw: Your participation in this study is voluntary. You may withdraw from the study at any time. This will not affect your child's treatment in any way. You can also choose to have your data removed from the databases at any time.

Contacts: You will be given a copy of this consent form. If you have any further questions about the study, please call Gayatri Kembhavi at 471-2262, ext. 2280.

Additional Contacts: If you have any concerns about any aspect of this study, you may contact the Patient Concerns Office of the Capital Health Authority at 474-8892. This office has no affiliation with the study investigators.

APPENDIX E:

CONSENT FORM

APPENDIX E

Title of Project:	**The Berg Balance Scale: validation in a pediatric population**
Investigators:	Gayatri Kembhavi, Graduate Student Department of Physical Therapy, University of Alberta 471-7979
	Graduate Supervisor: Johanna Darrah, PhD Department of Physical Therapy, University of Alberta 492-9142

Do you understand that your child has been asked to be in a research study?	Yes	No
Have you read and received a copy of the attached Information Sheet?	Yes	No
Do you understand the benefits and risks to your child taking part in this research study?	Yes	No
Have you had an opportunity to ask questions and discuss this study?	Yes	No
Do you understand that you or your child are free to refuse to participate or withdraw from the study at any time? You or your child do not have to give a reason and it will not affect your child's care.	Yes	No
Has the issue of confidentiality been explained to you? Do you understand who will have access to your child's records?	Yes	No

This study was explained to me by:______________________________

I agree to take part in this study.

______________________________ Signature of parent/guardian	______________ Date	______________________________ Signature of Child
______________________________ Printed Name		______________________________ Printed Name

I believe that the person signing this form understands what is involved in the study and voluntarily agrees to participate.

____ Signature of Investigator or Designee	______________ Date

APPENDIX F:

GROSS MOTOR FUNCTION MEASURE- EXCERPTS

Item	D: STANDING	SCORE				
52.	ON THE FLOOR: PULLS TO STD AT LARGE BENCH	0☐	1☐	2☐	3☐	52.
53.	STD: MAINTAINS, ARMS FREE, 3 SECONDS	0☐	1☐	2☐	3☐	53.
54.	STD: HOLDING ON TO LARGE BENCH WITH ONE HAND, LIFTS R FOOT, 3 SECONDS	0☐	1☐	2☐	3☐	54.
55.	STD: HOLDING ON TO LARGE BENCH WITH ONE HAND, LIFTS L FOOT, 3 SECONDS	0☐	1☐	2☐	3☐	55.
56.	STD: MAINTAINS, ARMS FREE, 20 SECONDS	0☐	1☐	2☐	3☐	56.
57.	STD: LIFTS L FOOT, ARMS FREE, 10 SECONDS	0☐	1☐	2☐	3☐	57.
58.	STD: LIFTS R FOOT, ARMS FREE, 10 SECONDS	0☐	1☐	2☐	3☐	58.
59.	SIT ON SMALL BENCH: ATTAINS STD WITHOUT USING ARMS	0☐	1☐	2☐	3☐	59.
60.	HIGH KN: ATTAINS STD THROUGH HALF KN ON R KNEE, WITHOUT USING ARMS	0☐	1☐	2☐	3☐	60.
61.	HIGH KN: ATTAINS STD THROUGH HALF KN ON L KNEE, WITHOUT USING ARMS	0☐	1☐	2☐	3☐	60.
62.	STD: LOWERS TO SIT ON FLOOR WITH CONTROL, ARMS FREE	0☐	1☐	2☐	3☐	62.
63.	STD: ATTAINS SQUAT, ARMS FREE	0☐	1☐	2☐	3☐	63.
64.	STD: PICKS UP OBJECT FROM FLOOR, ARMS FREE, RETURNS TO STAND	0☐	1☐	2☐	3☐	64.

Item	E. WALKING, RUNNING AND JUMPING	SCORE				
65.	STD, 2 HANDS ON LARGE BENCH: CRUISES 5 STEPS TO R	0☐	1☐	2☐	3☐	65.
66.	STD, 2 HANDS ON LARGE BENCH: CRUISES 5 STEPS TO L	0☐	1☐	2☐	3☐	66.
67.	STD, 2 HANDS HELD: WALKS FORWARD 10 STEPS	0☐	1☐	2☐	3☐	67.
68.	STD, 1 HAND HELD: WALKS FORWARD 10 STEPS	0☐	1☐	2☐	3☐	68.
69.	STD: WALKS FORWARD 10 STEPS	0☐	1☐	2☐	3☐	69.
70.	STD: WALKS FORWARD 10 STEPS, STOPS, TURNS 180°, RETURNS	0☐	1☐	2☐	3☐	70.
71.	STD: WALKS BACKWARD 10 STEPS	0☐	1☐	2☐	3☐	71.
72.	STD: WALKS FORWARD 10 STEPS, CARRYING A LARGE OBJECT WITH 2 HANDS	0☐	1☐	2☐	3☐	72.
73.	STD: WALKS FORWARD 10 CONSECUTIVE STEPS BETWEEN PARALLEL LINES 8" APART	0☐	1☐	2☐	3☐	73.
74.	STD: WALKS FORWARD 10 CONSECUTIVE STEPS ON A STRAIGHT LINE ¾" WIDE	0☐	1☐	2☐	3☐	74.
75.	STD: STEPS OVER STICK AT KNEE LEVEL, R FOOT LEADING	0☐	1☐	2☐	3☐	75.
76.	STD: STEPS OVER STICK AT KNEE LEVEL, L FOOT LEADING	0☐	1☐	2☐	3☐	76.
77.	STD: RUNS 15 FEET, STOPS & RETURNS	0☐	1☐	2☐	3☐	77.
78.	STD: KICKS BALL WITH R FOOT	0☐	1☐	2☐	3☐	78.
79.	STD: KICKS BALL WITH L FOOT	0☐	1☐	2☐	3☐	79.
80.	STD: JUMPS 12" HIGH, BOTH FEET SIMULTANEOUSLY	0☐	1☐	2☐	3☐	80.
81.	STD: JUMPS FORWARD 12", BOTH FEET SIMULTANEOUSLY	0☐	1☐	2☐	3☐	81.
82.	STD ON R FOOT: HOPS ON R FOOT 10 TIMES WITHIN A 24" CIRCLE	0☐	1☐	2☐	3☐	82.
83.	STD ON L FOOT: HOPS ON L FOOT 10 TIMES WITHIN A 24" CIRCLE	0☐	1☐	2☐	3☐	83.
84.	STD, HOLDING 1 RAIL: WALKS UP 4 STEPS, HOLDING 1 RAIL, ALTERNATING FEET	0☐	1☐	2☐	3☐	84.
85.	STD, HOLDING 1 RAIL: WALKS DOWN 4 STEPS, HOLDING 1 RAIL, ALTERNATING FEET	0☐	1☐	2☐	3☐	85.
86.	STD: WALKS UP 4 STEPS, ALTERNATING FEET	0☐	1☐	2☐	3☐	86.
87.	STD: WALKS DOWN 4 STEPS, ALTERNATING FEET	0☐	1☐	2☐	3☐	87.
88.	STD ON 6" STEP: JUMPS OFF, BOTH FEET SIMULTANEOUSLY	0☐	1☐	2☐	3☐	88.

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APPENDIX G:

GROSS MOTOR FUNCTION CLASSIFICATION SYSTEM FOR CEREBRAL PALSY (EXCERPTS)

GROSS MOTOR FUNCTION CLASSIFICATION SYSTEM (EXCERPTS)

Level I
Walks without restrictions; limitations in more advanced gross motor skills.

1 - 2 years of age: Infants move in and out of sitting and floor sit with both hands free to manipulate objects. Infants crawl on hands and knees, pull to stand and take steps holding onto furniture. Infants walk between 18 months and 2 years of age without the need for any assistive mobility device.

2 – 4 years of age: Children floor sit with both hands free to manipulate objects. Movements in and out of floor sitting and standing are performed without adult assistance. Children walk as the preferred method of mobility without the need for any assistive mobility device.

4 – 6 years of age: Children get into and out of, and sit in, a chair without the need for hand support. Children move from the floor and from chair sitting to standing without the need for objects for support. Children walk indoors and outdoors, and climb stairs. Emerging ability to run and jump.

6 – 12 years of age: Children walk indoors and outdoors, and climb stairs without limitations. Children perform gross motor skills including running and jumping <u>but</u> speed, balance, and coordination are reduced.

Level II
Walks without assistive devices; limitations walking outdoors and in the community.

1 – 2 years of age: Infants maintain floor sitting but may need to use their hands for support to maintain balance. Infants creep on their stomach or crawl on hands and knees. Infants may pull to stand and take steps holding onto furniture.

2 – 4 years of age: Children floor sit <u>but</u> may have difficulty with balance when both hands are free to manipulate objects. Movements in and out of sitting are performed without adult assistance. Children pull to stand on a stable surface. Children crawl on hands and knees with a reciprocal pattern, cruise holding onto furniture and walk using an assistive mobility device as preferred methods of mobility.

4 – 6 years of age: Children sit in a chair with both hands free to manipulate objects. Children move from floor to standing and from chair sitting to standing but often require a stable surface to push or pull up on with their arms. Children walk without the need for any assistive mobility device indoors and for short distances on level surfaces outdoors. Children climb stairs holding onto a railing <u>but</u> are unable to run and jump.

6 – 12 years of age: Children walk indoors and outdoors, and climb stairs holding onto a railing but experience limitations walking on uneven surfaces and inclines, and walking in crowds or confined spaces. Children have at best only minimal ability to perform gross motor skills such as running and jumping.

Level III
Walks with assistive mobility devices; limitations walking outdoors and in the community.

1 – 2 years of age: Infants maintain floor sitting when the low back is supported. Infants roll and creep forward on their stomachs.

2 – 4 years of age: Children maintain floor sitting often by "W-sitting" (sitting between flexed and internally rotated hips and knees) and may require adult assistance to assume sitting. Children creep on their stomach or crawl on hands and knees (often without reciprocal leg movements) as their primary methods of self-mobility. Children may pull to stand on a stable surface and cruise short distances. Children may walk short distances indoors using an assistive mobility device and adult assistance for steering and turning.

4 – 6 years of age: Children sit on a regular chair but may require pelvic or trunk support to maximize hand function. Children move in and out of chair sitting using a stable surface to push on or pull up with their arms. Children walk with an assistive mobility device on level surfaces and climb stairs with assistance from an adult. Children frequently are transported when traveling for long distances or outdoors on uneven terrain.

6 – 12 years of age: Children walk indoors and outdoors on a level surface with an assistive mobility device. Children may climb stairs holding onto a railing. Depending on upper limb function, children propel a wheelchair manually or are transported when traveling for long distances or outdoors on uneven terrain.

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